FORECASTING NEEDS FOR THE HIGH TECHNOLOGY INDUSTRY

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-SEVENTH CONGRESS

FIRST SESSION

NOVEMBER 24, 1981

[No. 67]

Printed for the use of the
Committee on Science and Technology

U.S. GOVERNMENT PRINTING OFFICE
89-542 O WASHINGTON: 1982

H701-35

COMMITTEE ON SCIENCE AND TECHNOLOGY

DON FUQUA, Florida, *Chairman*

ROBERT A. ROE, New Jersey
GEORGE E. BROWN, JR., California
JAMES H. SCHEUER, New York
RICHARD L. OTTINGER, New York
TOM HARKIN, Iowa
MARILYN LLOYD BOUQUARD, Tennessee
JAMES J. BLANCHARD, Michigan
TIMOTHY E. WIRTH, Colorado*
DOUG WALGREN, Pennsylvania
RONNIE G. FLIPPO, Alabama
DAN GLICKMAN, Kansas
ALBERT GORE, JR., Tennessee
ROBERT A. YOUNG, Missouri
RICHARD C. WHITE, Texas
HAROLD L. VOLKMER, Missouri
HOWARD WOLPE, Michigan
BILL NELSON, Florida
BERYL ANTHONY, JR., Arkansas*
STANLEY N. LUNDINE, New York
ALLEN E. ERTEL, Pennsylvania
BOB SHAMANSKY, Ohio
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
MERVYN M. DYMALLY, California

LARRY WINN, JR., Kansas
BARRY M. GOLDWATER, JR., California
HAMILTON FISH, JR., New York
MANUEL LUJAN, New Mexico
HAROLD C. HOLLENBECK, New Jersey
ROBERT S. WALKER, Pennsylvania
EDWIN B. FORSYTHE, New Jersey
WILLIAM CARNEY, New York
MARGARET M. HECKLER, Massachusetts
F. JAMES SENSENBRENNER, JR., Wisconsin
VIN WEBER, Minnesota
JUDD GREGG, New Hampshire
RAYMOND J. McGRATH, New York
JOE SKEEN, New Mexico
CLAUDINE SCHNEIDER, Rhode Island
JIM DUNN, Michigan
BILL LOWERY, California

HAROLD P. HANSON, *Executive Director*
PHILIP B. YEAGER, *General Counsel*
REGINA A. DAVIS, *Administrator*
GERALD E. JENKS, *Minority Staff Director*

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

DOUG WALGREN, Pennsylvania, *Chairman*

GEORGE E. BROWN, JR., California
BOB SHAMANSKY, Ohio
MERVYN M. DYMALLY, California
STANLEY N. LUNDINE, New York
ALLEN E. ERTEL, Pennsylvania
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma

MARGARET M. HECKLER, Massachusetts
VIN WEBER, Minnesota
JUDD GREGG, New Hampshire
JOE SKEEN, New Mexico
EDWIN B. FORSYTHE, New Jersey

*On assignment to Budget Committee for 97th Congress.

CONTENTS

WITNESSES

November 24, 1981:	Page
Roger Wellington, president, Augat, Inc., and board member, Massachusetts High Technology Council and chairman, New England Council, American Electronics Association; Tom Farrington, president, Input-Output Computer Services, Inc., and Charles McKay, executive vice president, Foxboro Co	11
Charles Coulter, president, American Research and Developement	50
Robert Henderson, president, Itek Corp.; Robert Seamans, Henry R. Luce, Professor of Environmental and Public Policy, Massachusetts Institute of Technology; and Kenneth Ryder, president, Northeastern University, accompanied by Barbara Kahn	55
Herbert J. Hollomon, director, Center for Policy Alternatives, M.I.T	122
Michael Rooney, president, Boston Systems Office, Inc	130
Appendix: Prepared statement submitted by Malcolm Baldrige	135
Prepared statement submitted by W. A. Baylies	148
Prepared statement submitted by Richard A. LaBrie	154
Prepared statement submitted by Dr. Julian J. Bussgang	155
Prepared statement submitted by Pat Hill Hubbard	145
Prepared statement submitted by Massachusetts Division of Employment Security	195
Prepared statement submitted by Peter B. Doeringer and Patricia Pannell	218
Prepared statement submitted by the Center for Research and Business Activity, College of Business and Industry, Southeastern Massachusetts University	255

FORECASTING NEEDS FOR THE HIGH TECHNOLOGY INDUSTRY

TUESDAY, NOVEMBER 24, 1981

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:30 a.m., in the Little Theatre, Kresge Auditorium, Massachusetts Institute of Technology, Cambridge, Mass., Hon. Margaret M. Heckler, presiding.

[The opening remarks of Mr. Walgren and Mrs. Heckler follow:]

OPENING REMARKS
OF
HON. DOUG WALGREN
AT HEARINGS OF SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY
NOVEMBER 24, 1981

IT IS A PLEASURE TO BE HERE THIS MORNING TO PARTICIPATE IN HEARINGS ON THE PRESENT AND FUTURE STATE OF HIGH TECHNOLOGY INDUSTRY. IT IS PARTICULARLY APPROPRIATE THAT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY IS HOSTING THIS HEARING SINCE MIT HAS PLAYED SUCH A KEY ROLE IN THE DEVELOPMENT OF HIGH TECHNOLOGY INDUSTRIES IN THE BOSTON AREA.

THE SUBCOMMITTEE HAS BEEN STUDYING UNIVERSITY-INDUSTRY RELATIONS FOR SOME TIME AND HAS HELD MIT UP AS A SHINING EXAMPLE. THE COUNTRY NEEDS TO DEVELOP MORE UNIVERSITY-INDUSTRY COOPERATION OF THE SORT YOU HAVE HERE.

THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY HAS HAD A CONTINUING PROGRAM IN INNOVATION AND PRODUCTIVITY. WE HAVE HELD SOME 40 SESSIONS OF HEARINGS IN THIS PROGRAM OVER

THE LAST THREE YEARS. THIS YEAR HEARINGS HAVE FOCUSSED ON IMPLEMENTATION OF THE STEVENSON-WYDLER TECHNOLOGY INNOVATION ACT OF 1980 AND ON THE HUMAN FACTOR IN INNOVATION AND PRODUCTIVITY. THE FULL COMMITTEE ON SCIENCE AND TECHNOLOGY, PARTICULARLY OUR CHAIRMAN DON FUQUA OF FLORIDA, HAS ALSO BEEN ACTIVE IN UNIFORM FEDERAL PATENT POLICY, SMALL BUSINESS INNOVATION AND TAX POLICY TO STIMULATE INNOVATION.

I WOULD LIKE TO CONGRATULATE MY COLLEAGUE CONGRESSWOMAN MARGARET HECKLER FOR TAKING THE LEAD IN ORGANIZING TODAY'S HEARING. WE HAVE AN IMPRESSIVE SCHEDULE OF WITNESSES HEADED BY SECRETARY BALDRIGE OF THE DEPARTMENT OF COMMERCE, AND I AM LOOKING FORWARD TO HEARING THEIR TESTIMONY. I APPRECIATE THEIR WILLINGNESS TO PARTICIPATE IN THIS HEARING.

THE HONORABLE MARGARET M. HECKLER

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

FORECASTING NEEDS: THE HIGH TECHNOLOGY INDUSTRY

KRESGE AUDITORIUM, M.I.T.

24 NOVEMBER 1981

THANK YOU MR. WALGREN.

I WOULD LIKE TO THANK THE CHAIRMAN FOR JOINING ME IN CALLING FOR THIS HEARING ON THE NEEDS OF THE HIGH TECHNOLOGY INDUSTRY. UNDER MR. WALGREN'S LEADERSHIP, THE SUBCOMMITTEE HAS HELD SEVERAL HEARINGS RELATED TO THE HIGH TECH INDUSTRY INCLUDING:COORDINATED HEALTH INFORMATION SYSTEMS, INDUSTRY/UNIVERSITY RELATIONSHIPS, BIOTECHNOLOGY, INNOVATION AND PRODUCTIVITY, AND NATIONAL INFORMATION SYSTEMS POLICY. HE HAS ALSO SUPPORTED SUBCOMMITTEE EFFORTS TO REFORM FEDERAL PATENT POLICY AND THE INCREASED DISSEMINATION OF FEDERALLY SPONSORED R&D THROUGH THE MULTITUDE OF FEDERAL LABORATORIES AROUND THE COUNTRY.

THE HEARING TODAY REPRESENTS A CONTINUATION OF THE SUBCOMMITTEE'S INVESTIGATION INTO INNOVATION AND PRODUCTIVITY . SPECIFICALLY , THE SUBCOMMITTEE WILL TODAY TAKE A CLOSE LOOK AT THAT GROUP OF INDUSTRIES NOW REFERRED TO AS HIGH TECHNOLOGY. THIS COLLECTION OF INDUSTRIES, WITH SOME PARTICULAR EXCEPTIONS, HAS PROVED TO BE ONE OF THE HIGHEST GROWTH INDUSTRIES IN THE NATION. ACCORDING TO

A RECENT WALL STREET JOURNAL ARTICLE, COMPUTERS AND INFORMATION PROCESSING WILL BE THE WORLD'S BIGGEST BUSINESS, SECOND ONLY TO PETROLEOM. LEVELS OF INNOVATION AND PRODUCTIVITY ARE NOT ONLY IMPORTANT WITHIN THE HIGH TECH INDUSTRY, BUT IN VIRTUALLY ALL OTHER SECTORS OF THE NATIONAL ECONOMY AS WELL, SINCE THE PRODUCTS OF THE HIGH TECHNOLOGY INDUSTRY PERCOLATE PRODUCTIVITY IMPROVEMENTS THROUGHOUT AMERICAN INDUSTRY.

A NUMBER OF ISSUES HAVE APPEARED ON THE HORIZON THAT WILL HAVE SOME BEARING ON THE CONTINUED PROSPERITY OF THE HIGH TECHNOLOGY INDUSTRY. A GROWING SHORTAGE OF TECHNICAL PROFESSIONALS AND PARAPROFESSIONALS IS CAUSING GREAT CONCERN IN THE INDUSTRY AND IS PUTTING PRESSURE ON THE NATION'S UNIVERSITIES. A SHORTFALL OF 17,000 ELECTRICAL ENGINEERS IN 1981 IS THE RESULT OF AN ALMOST 300% GROWTH RATE IN THE INDUSTRY (DURING THE LAST 10 YEARS) WHILE THE NUMBER OF ELECTRICAL ENGINEERS HAS REMAINED VIRTUALLY THE SAME.

THE AMERICAN ELECTRONICS ASSOCIATION HAS RECENTLY TESTIFIED BEFORE THE JOINT ECONOMIC COMMITTEE, WHERE I AM A MEMBER, THAT THE OUTPUT OF ENGINEERS WILL HAVE TO TRIPLE EVERY YEAR FOR THE NEXT FIVE YEARS IN ORDER TO ELEVIATE AN ESTIMATED 129,000 PERSON SHORTFALL BY 1985. THE COLLEGE PLACEMENT COUNCIL REPORTS THAT 65% OF THE JOB OFFERS THEY RECEIVED LAST YEAR WERE FOR ENGINEERS, WHO REPRESENTED ONLY 8% OF THE GRADUATING POPULATION.

THE SHORTAGE IS MUCH BROADER THAN SIMPLY ENGINEERS; THERE IS ALSO A GROWING NEED FOR COMPUTER SCIENTISTS, SOLID STATE PHYSICISTS, AND CHEMISTS. THE SLIGHTLY LESS TECHNICAL FIELDS ARE ALSO FEELING THE PINCH; THESE INCLUDE : COMPUTER PROGRAMMERS, SYSTEMS ANALYSTS, DRAFTERS, AND OTHER COMPUTER SPECIALISTS.

WHILE THERE IS DISAGREEMENT ON THE SEVERITY OF THE SHORTAGE, THE CONGRESS NEEDS TO ADDRESS THE PERSONEL PROBLEM BOTH TO ENSURE CONTINUED PRODUCTIVITY WITH IN THE INDUSTRY AND TO MAINTAIN OUR STANDING WITH INTERNATIONAL COMPETITORS. FOR EXAMPLE, THE JAPANESE PRODUCE 35% MORE ENGINEERS THAN WE DO, WITH ONLY 1/2 THE POPULATION. OF LAST YEAR'S 523 PH.D.'S IN ELECTRICAL ENGINEERING, 33% WERE FOREIGN STUDENTS, MOST OF THEM ON STUDENT VISAS.

THE TRAINING OF TECHNICAL PROFESSIONALS IS ONLY ONE ASPECT OF FOREIGN COMPETITION THAT CONCERNS AMERICAN INDUSTRY. WHILE THE JAPANESE CURRENTLY HOLD 10% OF THE DATA-PROCESSING MARKET, THEY ARE EXPECTED TO INCREASE THAT SHARE BY 50% IN THE NEXT FOUR YEARS. MORE SIGNIFICANT ARE THE PARTICULAR TECHNOLOGIES, LIKE MEMORY CHIPS, WHERE THE JAPANESE APPEAR DETERMINED TO GAIN MARKET CONTROL.

IF THE COMPETITION WAS BASED ON THE SAME RULE BOOK FOR ALL PLAYERS THEN AMERICAN INDUSTRY COULD HAVE NO COMPLAINTS, AND WOULD CERTAINLY REMAIN THE LEADER IN ALMOST ALL FIELDS. IT IS UNFORTUNATE THAT THE COMPETITORS ARE NOT RUNNING THE SAME RACE.

SOME, LIKE THE JAPANESE FIRMS, RUN EASIER DUE TO GOVERNMENT FUNDED R & D. OUR COMPETITORS ALSO BENEFIT FROM GOVERNMENT SUPPORT VIA IMPORT RESTRICTIONS AND EXPORT SUBSIDIES. THE CONGRESS SHOULD ACT TO GUARANTEE AS FREE AN INTERNATIONAL MARKET PLACE AS POSSIBLE.

THE SUBCOMMITTEE IS ALSO CONCERNED ABOUT THE CAPITAL NEEDS OF THE HIGH TECHNOLOGY INDUSTRY. THERE ARE TREMENDOUS FUNDING REQUIREMENTS DUE TO HIGH GROWTH RATES AND THE NEED TO AUTOMATE AND STREAMLINE MANUFACTURING OPERATIONS AS PROFIT MARGINS CONTINUE TO DECLINE. THE SUBCOMMITTEE IS INTERESTED TO LEARN HOW CAPITAL AVAILABILITY MIGHT IMPEDE INDUSTRIAL EXPANSION, IF AT ALL.

WE ARE PLEASED TO HAVE WITH US TODAY A NUMBER OF DISTINGUISHED INDIVIDUALS WHO WILL PRESENT TESTIMONY ON THESE MATTERS. I WOULD LIKE TO THANK YOU ALL FOR COMING TODAY, ESPECIALLY DR. HOLLOMAN FROM MIT AND MICHAEL ROONEY, THE PRESIDENT OF BOSTON SYSTEMS OFFICE, INC., FOR COMING ON SUCH SHORT NOTICE.

LET ME SAY AT THE OUTSET THAT THE ENTIRE HEARING PROCEEDINGS, INCLUDING WRITTEN TESTIMONY SUBMITTED FOR THE RECORD, WILL BE PUBLISHED BY THE SUBCOMMITTEE. IF YOU WOULD LIKE TO RECEIVE A COPY DO BE SURE TO LEAVE YOUR ADDRESS AT THE REGISTRATION TABLE IN THE LOBBY IF HAVEN'T DONE SO ALREADY.

Mr. WALGREN. Let me open our proceedings this morning and welcome you.

It is a great pleasure for me to be in Boston. I represent a district from Pittsburgh, Pa., in the U.S. Congress and have served on the Science and Technology Committee and chair the Subcommittee on Science, Research and Technology, on which Mrs. Heckler is the ranking minority member.

We are chairmen or ranking minority members more by the grace of the election results than anything else. I happen to be a Democrat; Mrs. Heckler, of course, happens to be a Republican. The truth of it is that the Congress is a small body, particularly when you get down to the committee and subcommittee size, so that there is a very real equal standing among the members and there are some very good things that flow out of that: therefore, I am going to ask Mrs. Heckler to be the chair of this meeting. We really play a very similar role in the committee.

The area of science and technology, particularly the Government role in supporting basic research and encouraging business activity, and the breaking of new ground, is an area that is not normally broken down along partisan lines. Because of that, there is an increased influence and leverage by the people who serve on the committees that are involved in that area.

When bills from the Science and Technology Committee come to the floor of the House of Representatives, there is a great deal of deference given to the judgments that are made in the committee. So, consequently, your community here is very fortunate to have a representative as interested in this area as Mrs. Heckler.

As a subcommittee, we have been studying university/industry relations and the kinds of university/industry cooperation that we are looking forward to in the development of science. The committee has also been very involved in the overall issues of how do you encourage innovation and productivity.

We have been particularly involved in the Stevenson-Wydler Technology Innovation Act and have held a number of hearings this year on human factors in productivity.

I want to particularly recognize the contribution that Mrs. Heckler has made in bringing the questions that relate to high technology to the attention of our committee, myself and the other members.

It is an interest that is very specific with the Boston area, and since you have a very strong advocate and one who has pursued that interest in the Congress.

I want to ask Mrs. Heckler to chair the committee inasmuch as she has been the focal point of our committee's interest in this area.

I am very pleased to be here with you and look forward to learning what I can from the presentations that are made today and look forward to working with you in making the ideas that are expressed have weight and make a contribution to national policy overall.

So, thank you for directing the committee in this direction and inviting me to come.

Mrs. HECKLER. Thank you very much, Mr. Chairman.

It is certainly a pleasure to have you in Boston. I want to say we are fortunate to have a chairman who has a comprehensive understanding of the broad problems of the scientific community and is a strong advocate for the development of that community domestically.

It is a pleasure to have our colleague, Judd Gregg, who came from New Hampshire to be with us today. While we do not wish—speaking provincially—a spillover of our high technology to be excessive into New Hampshire, we are glad New Hampshire shares a measure of concern with the issue and that their own development has been considerable in this field.

Judd Gregg is a new Member of Congress who has made a very strong contribution. I think his presence here today is quite clear evidence of the concerns that he has in his congressional service.

I feel that the hearing today is of enormous significance. Under Mr. Walgren's leadership in Washington, the subcommittee held several hearings relating to the high technology industry. These included coverage of the subjects of coordinated health information services, industry/university relationships, biotechnology innovation and productivity, and national information systems policy.

Chairman Walgren has also supported subcommittee efforts to reform Federal patent policy and the increased dissemination of federally-sponsored R. & D. through the multitude of Federal laboratories across the country.

The hearing today represents a continuation of the subcommittee's investigation into innovation and productivity. Specifically, the subcommittee will today take a close look at that group of industries now referred to as high technology. This collection of industries with some exceptions, has proved to be one of the highest growth industries in the Nation.

According to a recent Wall Street Journal article, computers and information processing will be the world's biggest business, second only to petroleum.

Levels of innovation and productivity are not only important within the high technology industry, but to virtually all other sectors of our national economy and, since the products of the high technology industry percolate improvement throughout American industry, the subject of the growth and health of the high technology industry is, therefore, a very important national problem.

A number of issues have appeared on the horizon that will have some bearing on the continued prosperity of high technology. A growing shortage of technical professionals and paraprofessionals is causing great concern in the university community. A shortfall of 17,000 electrical engineers in 1981 is the result of an almost 300-percent growth rate in the industry itself during the last 10 years, while the number of electrical engineers has remained virtually the same.

The American Electronics Association has recently testified before the Joint Economic Committee, on which I also serve, that the output of engineers will have to triple every year for the next 5 years in order to alleviate an estimated 129,000-person shortfall by 1985.

The College Placement Council reports that 65 percent of the job offers they received last year were for engineers who represented only 8 percent of the graduating population.

The shortage is much broader than simply engineers. There is also a need for computer scientists, solid-state physicists, and chemists. Slightly less technical fields are also feeling the pinch; these include computer programers, system analysts, drafters, and other computer specialists. While there is disagreement on the severity of the shortage, the Congress needs to address the personnel problem, both to insure continued productivity in the industry and to maintain our standing with international competitors.

For example, the Japanese produce 35 percent more engineers than we do with only one-half the population. That is an incredible figure. Of last year's 523 Ph. D.'s in electrical engineering, 33 percent were foreign students; most of them on student visas.

The training of technical professionals is only one aspect of foreign competition that concerns American industry. While the Japanese currently hold 10 percent of the data processing market, they are expected to increase that share by 50 percent in the next 4 years.

More significant are the particular technologies like memory chips where the Japanese are determined to gain market approval and control.

If the competition was based on the same rule book for all players, then American industry would have no complaints and would certainly remain the leader in almost all fields. It is unfortunate that the competitors are not running in the same race with the same ground rules. Some, like the Japanese firms, run far more easily due to government-funded R. & D.

Our competitors also benefit from government support via import restrictions and export subsidies. The Congress should act to guarantee as free an international marketplace as possible if we are going to compete effectively.

This subcommittee is also concerned about the capital needs of the high technology industry. There are tremendous funding requirements due to high growth rates and the need to automate and streamline manufacturing operations as profit margins continue to decline. The subcommittee is interested to learn how capital availability might impede industrial expansion if at all and what, if anything, Congress can do about it.

We are pleased to have with us today a number of distinguished individuals who will present testimony on these matters. I would like to thank all of the witnesses for coming, to say that we especially thank Dr. Hollomon from MIT and Michael Rooney, the president of the Boston Systems Office, Inc., for coming on very short notice.

Let me say the entire proceedings, including written testimony submitted for the written record, will be published by the subcommittee.

We are fortunate in having with us today some experts in the field of high technology from both the industry levels and from academia. We look forward to their testimony. I would like to proceed and call forward as witnesses the first panel, Roger Wellington, president of Augat and board member of the Massachusetts

High Technology Council; Tom Farrington, president of Input-Output Computer Services, Inc., and Charles McKay, executive vice president of the Foxboro Co.

Please come to the witness table, gentlemen.

TESTIMONY OF ROGER WELLINGTON, CHAIRMAN OF THE BOARD, AUGAT INC., AND BOARD MEMBER, MASSACHUSETTS HIGH TECHNOLOGY COUNCIL AND CHAIRMAN, NEW ENGLAND COUNCIL, AMERICAN ELECTRONICS ASSOCIATION; TOM FARRINGTON, PRESIDENT, INPUT-OUTPUT COMPUTER SERVICES, INC.; AND CHARLES McKAY, EXECUTIVE VICE PRESIDENT, FOXBORO CO.

Mrs. HECKLER. We will proceed.

I would like to ask the panel to give their testimony and then the members of the committee will proceed with questions at the conclusion of your remarks.

Mr. WELLINGTON. Thank you.

First, I would like to ask your permission to speak and paraphrase my statement.

The complete statement is for the record. It may be in the interests of time to do so.

Mrs. HECKLER. So ordered.

Mr. WELLINGTON. I am the chairman of the board and chief executive officer of Augat, with approximately 3,100 employees and 8 plants in Massachusetts and additional manufacturing facilities in New Jersey, New York, Florida, Texas, California, and Switzerland.

This statement is being offered also in my capacity as a director of the American Electronics Association and chairman of its New England chapter, where I also serve as a director of the Massachusetts High Technology Council.

Many of the statements and much of the statistical information that I will include in this testimony comes from the Blue Ribbon Committee on Engineering Education chaired by Dr. William Perry, former Under Secretary of Defense for Research and Engineering.

Also included is statistical information derived from studies made by the American Electronics Association and the Massachusetts High Technology Council.

The critical problem is that we do not have a depth understanding throughout the country of the high technology shortage in engineering and the negative impact that this will make on the economic and political leadership of the country.

This is the fastest growing and most economically prized sector of the American economy. It has had an annual compounded growth rate of 17 percent during the past decade.

The total industry sales now are approximately $100 billion. The computer sector alone accounted for $6 billion of trade surplus in the past year.

A 1981 panel on computing and higher education quotes a Commerce Department report that says the broadest view of information technology plays a role in almost 46 percent of the gross national product.

The critical nature of this shortage Congresswoman Heckler already alluded to, that there is a shortfall in electronic engineering and computer science degreed engineering of approximately 25,000 per annum through 1985.

The demographic problem in the United States will add further complication to this beyond 1985 if the current trends continue.

This is simply due to the decline in college age population which will be lower in the 1985–90 period.

We would have to triple our current output of engineers to solve this problem, which is simply not possible, not in the short range.

If there is no alleviation in 1985 and beyond, we will continue to suffer very badly, both from a political and economic standpoint.

The international perspective of this situation is particularly dramatic if one considers the statement of 35 percent more engineers being graduated with half the population, which has cumulatively resulted in Japan today having five times as many engineers on a per capita basis as the United States.

It is a society that puts a premium on technology. There are one-twentieth of the lawyers in Japan per capita and one-seventh of the accountants. Of great discomfiture, I think, also to the United States in its military position, its defense position, is that the Soviet Union is graduating six times as many engineers as the United States at the undergraduate level.

We have become a nation of fourth-rank in scientific literacy, behind the Soviet Union, Germany, and Japan.

From the standpoint of the cause of the problem, the AEA Blue Ribbon Committee has discussed many problems of attitude from both the viewpoint of the industry and the educators; but there is little divergence of opinion with regard to several points.

First, the undergraduate or the applicant supply.

During 1970–71, we in New England were quite familiar with this: engineers laid off due to aerospace and defense programs. It became a media cause celebre. Reports emphasized job losses.

Actually, the unemployment rate for engineers during that period reached 3.2 percent briefly, before returning to its normal level of approximately 1 percent.

The public's distorted view of the so-called engineering bust, along with the antitechnology fashion of the Vietnam period caused young people to avoid engineering careers for several years.

Today, however, the situation has reversed and engineering is the second most favored choice of today's high school seniors.

Estimates of the applicant to admission rate is placed at about 3 to 1.

Most engineering schools report far more applicants than available places.

Joseph Pettit, the president of Georgia Tech, and a member of AEA's blue ribbon committee on education and engineering, states that they approve admission for about 1,700 applicants out of a total of about 7,000 applicants.

The schools have been accommodating increased numbers of students. In the 287 engineering colleges and universities, this has increased 7.2 percent at the undergraduate and 7.1 percent at the graduate class level in 1980 compared to 1979.

There has been a steady increase in electrical engineering graduate degrees awarded since dropping to a low of 9,837 in 1977, its lowest level since 1970.

In 1980, 13,594 bachelor of science degrees in electrical engineering were awarded. However, at the graduate level, the trend is the reverse.

A total of 490 fewer master of science electrical engineering degrees were awarded in 1980, 3,660 or 11 percent less than the 4,150 in 1970.

Fewer than 350 Ph. D. electrical engineering degrees were awarded in 1980—as Mrs. Heckler said—523 less than the 873 awarded in 1970.

It is unlikely, however, that the increase in undergraduate degrees will continue and approach the need.

A recent Wall Street Journal article noted that all of the engineering schools are at capacity and crowded schools can't increase enrollment further.

Some are even cutting back. There is a broad concern that pushing resources beyond capacity may result in declining quality.

In summary, we have plenty of student applications, but too few resources to educate them without taking a risk in loss of quality.

There is an agreement that the problem also is related to outdated equipment. The engineering teaching equipment found in most university laboratories is 20 to 30 years old and the ability to teach growth technologies is almost nonexistent.

The cost of this equipment has skyrocketed. The provisions of the recent Economic Recovery Act of 1981 regarding deductibility for scientific equipment donated to colleges and universities will be a positive step to assist in solving this problem although, of course, much more is needed.

The facilities themselves, the brick and mortar, are also approaching on the average 30 years old.

Inflation, OSHA regulations, and laws requiring building accommodation for the handicapped have compounded universities' inability to provide money for upgrade, repair, or expansion of their teaching plans.

But the faculty shortage is the most critical problem. Of the Nation's 20,000 engineering faculty jobs, between 2,000 and 2,500, are unfilled.

In such fields as solid state electronics, computer engineering, digital systems, the National Science Foundation's Stephen Kahne places the shortage closer to 50 percent.

In 1980, only 8 percent—13 out of 160—of the new Stanford Ph. D.'s chose teaching against an estimate of 50 percent 10 years ago.

Mrs. Heckler spoke of the foreign students becoming an increasing percentage for the engineering doctoral pool. Of the 523 Ph. D. awards in electrical engineering, 66 percent went to foreign students on student visas and will be likely to go home.

The percentage of total foreign students applying for engineering Ph. D. degrees in 1964 was 19.8 percent. Today it is 46.3 percent.

They are the highest quality that their countries have to offer, but to remain in this country and teach, they face from 6 months to 2 years of immigration difficulties.

The industry/academia salary inequities are a great source of difficulty. Starting salaries in industry have now reached between $20,000 and $24,000 and few bachelor of science graduates have the incentive to continue their education.

The inequities increase at the Ph. D. level. The average salary for an assistant professor in 1980–81 was $21,758 a year.

Several years of doctoral study and 5 or more years of teaching must occur before academic salaries become interesting and seldom greater than industry.

Faculty unions are proving an obstacle to correcting this situation. A recent salary plan approved by California State College and University trustees to pay professors in business and engineering more than proves in other fields so that the colleges could compete with industry in hiring professors and reward merit has been met with strong opposition from two major faculty unions.

The unions are trying to overturn the plan by charging the proposal is the start of a spoils system that is demoralizing and giving preferential treatment to some professors.

This does not recognize the realities of the marketplace.

The dangers ahead, I believe, are clear. The phrase "crowding out" has become a familiar part of the economists' jargon when discussing the effect of the increased portion of the gross national product going to the public sector, crowding out funds for investment and growth in the private sector.

There is little information in the statistical projections that are included in this statement as to the effect on the engineering needs brought about by the increased programs of our defense industry.

Engineering shortages will become a major obstacle for defense contractors. Giving industry the contracts and the money will not find the people. High interest rates, high rentals and high housing prices have greatly reduced the mobility of personnel.

The great expansion of the 1970's in the electronics industry has occurred during a period of declining defense expenditures. The projections of the shortages of the eighties is largely without the needs of the defense industry which will be superimposed on these shortages.

There will be three likely unfavorable results: nonmilitary electronics; industry and defense contractors will compete doggedly with ever-increasing salaries for the inadequate supply of engineers.

The high technology industry will become less competitive in world markets. Costs of defense will vastly exceed expectations.

The faculty shortage will accelerate due to academia's inability to respond to the salary competition; "crowding out" of faculty needs will occur.

In addition to extreme cost overruns, the execution of defense programs will experience serious delays.

The engineering educators of the United States need help. There is a need for complete awareness on the part of the Federal Government and the Office of the President about the problem and the need for supportive fiscal and tax policies to solve it.

At the same time, industry associations must prepare to assist through programs to expand educational resources by increasing faculty and equipment.

Industrywide standards must be established for giving resources to engineering education.

Colleges, universities and their governing bodies may have to adjust historical practices in order to accommodate assistance from industry to supplement conventional tuition and public sources.

In closing, I would like to quote Stephen Kahne, Director of the Division of Electrical Computer and Systems Engineering at the National Science Foundation:

> It is no longer an open question whether the shortage of electrical engineers in the United States is or is not a crisis. It is.
>
> Sooner or later every U.S. industry dependent upon electrical engineering will be affected . . . and there are more such industries now than ever. Toy and automobile manufaturers, even textile and clothing companies, have discovered the value of electronics and computer-based systems in their products or manufacturing processes.
>
> Indeed, these new industries, previously unaffected by electrical engineering in any significant way, are the hidden factor that invalidates traditional market surveys of future needs for EEs. It is hard to predict the growing need for electronics specialists in sectors of the economy that never before employed them.

[The prepared statement of Mr. Wellington follows:]

STATEMENT BEFORE THE CONGRESSIONAL

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

NOVEMBER 24, 1981

M.I.T. KRESGE AUDITORIUM

Good morning. I am Roger D. Wellington, Chairman of the Board and Chief Executive Officer of Augat Inc., a Massachusetts based manufacturer and designer of a broad range of electromechanical interconnection products, services and precision materials for the electronics industry. Augat has 3100 employees with 8 plants in Massachusetts and additional manufacturing facilities in New Jersey, New York, Florida, Texas, California and Switzerland.

This statement is offered also in my capacity as a director of the American Electronics Association (AEA) and Chairman of its New England Chapter. I also serve as directors of the Massachusetts High Technology Council (MHTC) and Bay State Skills Corporation.

Many of the statements and much of the statistical information included in this testimony is drawn from a 1981 white paper prepared for the American Electronics Association by a Blue Ribbon Committee on Engineering Education chaired by Dr. William J. Perry, former Under Secretary of Defense for Research and Engineering. Other statistical information is from AEA and MHTC technical employment surveys.

THE PROBLEM

It is critical that the nation have a depth understanding that the national shortage of engineers threatens to limit the growth

of high technology and negatively impact the economic and political leadership of the United States. One of America's fastest-growing and most economically-prized high technology industries is electronics. It has had a compounded annual growth rate of 17% during the past decade[1] with total industry sales close to $200 billion in 1980.[2] A 1981 Panel on Computing and Higher Education quotes a Commerce Department report that says information technology accounts for 46% of the GNP, and computer sales alone bring a $6 billion balance of trade surplus.[3]

THE CRITICAL NATURE OF THE SHORTAGE

A shortfall exists between supply of engineering graduates and projected industry demands. The shortfall for the electronics industries alone projects to 25,000 EE/CS degreed engineers annually through 1985.[4]

Demographic factors in the United States will make the situation even more critical beyond 1985 if current trends continue. Due to decreases in college-age population the number of Bachelor degrees in engineering will be lower in 1990 than in 1985.[5]

To meet this demand education would have to triple its output. A result that is simply not possible. This dramatically states the problem and the urgency of immediate programs if there is to be any alleviation achieved in the 1985 and beyond period. In the meantime America's national interest, both economically and politically, will continue to seriously suffer.

THE INTERNATIONAL PERSPECTIVE

In the international economic arena where the battle for commercial leadership in electronics is taking place with Japan it is noteworthy that, on a per capita basis, Japan has 5 times as many engineers, but few than 1/20th of the lawyers, and 1/7th of the accountants as the United States.[6]

Of great discomfort to America's defense effort is the knowledge that the Soviet Union is graduating 6 times as many undergraduate engineers as the United States.[7]

In the fields of math and science, the United States has failed to educate its young in comparison to other nations. We now rank fourth in scientific literary, behind the Soviet Uniion, Germany, and Japan.[8]

SOME CAUSES OF THE ENGINEERING SHORTAGE

Although the AEA Blue Ribbon Committee report discusses problems of attitude from both the viewpoints of industry and educators, there is little divergence of opinion on these points.

. UNDERGRADUATE SUPPLY - During 1970-71, engineers laid off due to aerospace and defense programs became a media cause celebre. Reports emphasized job losses. Actually, the unemployment rate for engineers reach 3.2% for only "a brief time before returning to its normal level of about 1%."[9]

The public's distorted view of the engineering "bust" along with the anti-technology fashion of the Vietnam period caused young people to avoid engineering careers for several years. Today, the situation has reversed. Engineering is the second most favored choice of today's high school seniors.[10]

Estimates of the applicant-to-admission rate is placed at about 3-to-1. Most engineering schools report far more applicants than available places. Dr. Joseph Pettit, President of Georgia Institute of Technology and a member of AEA's Blue Ribbon Committee on Engineering Education, states that his college approves admission for about 1,700 of the approximately 7,000 applicants.

The schools have accommodated increased numbers of students. Full-time engineering undergraduate enrollments in the nation's 287 engineering colleges and universities increased 7.2% in undergraduate and 7.1% in graduate classes in 1980 compared to 1979.

There has been a steady increase in Electrical Engineering undergraduate degrees awarded since dropping to 9,837 in 1977 its lowest level since 1970. In 1980 13,594 BS/EE's were awarded.

At the graduate level the trend is the reverse. 490 fewer MS/EEs were awarded in 1980 (3,660), or 11.8% less than the 4,150 in 1970. 350 fewer PH.D/EE's were awarded in 1980 (523), or 40% less than the 873 awarded in 1970.

The increase in undergraduate degrees is unlikely to continue at a rate which will approach need. A recent Wall Street Journal article notes, engineering schools are "already at capacity" and "crowded schools can't increase enrollment further . . . . some are even cutting back." There seems to be a basis for concern that pushing resources beyond capacity may result in a decline in quality.

The present situation in engineering undergraduate education is characterized by plenty of students, but too few resources to educate them without risking a loss in quality.

OUTDATED EQUIPMENT - The engineering teaching equipment found in most university labs is 20-30 years old and equipment to teach new "growth technologies" is almost non-existent.[12] New technological processes, demanding sophisticated and costly equipment, have sky-rocketed the cost of teaching laboratories. Provisions of the Economic Recovery Act of 1981 regarding deductions for scientific equipment donated to colleges and universities will be a positive step to assist in solving this problem although, of course, much more is needed.

OUTDATED FACILITIES - Like equipment, most engineering labs and classrooms are now 30 years old. Inflation, OSHA regulations, and laws requiring building accommodations for the handicapped have compounded universities' inability to provide money for upgrade, repair, or expansion of their teaching plants.

FACULTY SHORTAGES - THE MOST CRITICAL PROBLEM Of the nation's 20,000 engineering faculty jobs, between 2,000 and 2,500 are unfilled. In fields such as solid-state electronics, computer engineering, and digital systems, NSF's Stephen Kahne places the shortage closer to 50%.[13] In 1980 only 8% (13 out of 160) of the new Standford PH.D's chose teaching last year versus an estimate of 50% ten years ago.[14]

Foreign students are an increasing percentage of the EE doctoral pool. Of the 523 PH.D/EE degrees awarded in 1980, 171 (33%) went to foreign students. Of these, 66% were on student visas and likely to return home.

ENGINEERING Ph.Ds

PERCENTAGE OF FOREIGN STUDENTS

1964 = 19.8%	1977 = 41.5%
1974 = 38.7%	1978 = 45.0%
1975 = 41.3%	1979 = 45.6%
1976 = 42.3%	1980 = 46.3%

Source: National Science Foundation

The majority of foreign students "are of very high caliber, among the best their country has, and graduate in the top fifth of their class."[15] Yet those who wish to remain in the U.S. face a lengthy 6 months to two years immigration process.

INDUSTRY-ACADEMIA SALARY INEQUITIES - With starting slaries in industry at $20,000 to $24,000, few BS graduates have the incentive to continue their education. The inequities increase as the PH.D is reached. The average salary for an Assistant Professor in 1980-81 was $21,758. Several years of doctoral study and five or more years of teaching must occur before academia's salaries become economically interesting . . . . and seldom greater than industry's. Faculty unions are proving an obstacle to correcting the situation.

> A recent salary plan approved by California State College and University trustees to pay professors in business and engineering more than professors in other fields, so that colleges could compete with industry and other schools in hiring professors and reward merit, has met with strong opposition from two major faculty unions. The unions, who are trying to overturn the plan, are charging that the proposal is the start of a "spoils system" that it is "demoralizing and would give preferential treatment" to some professors.[16]

THE DANGER AHEAD

The phase "crowding out" has become a familiar part of the economist jargon when discussing the effect of the increased portion of the GNP going to the public sector, crowding out funds for investment and growth in the private sector.

The statistics and projections included in this statement include little information as to effect on the engineering needs brought about by the increased programs of our defense industry. Engineering shortages will become a major obstacle for defense contractors. Giving industry the contracts and the money will not find the people. High interest rates, high rentals and high housing prices have greatly reduced the mobility of personnel.

The great expansion of the 70's in the electronics industry has occurred during a period of declining defense expenditures. The projections of the shortages of the 80's is largely without the needs of the defense industry which will be juxtaposed on these shortages.

There will be three likely unfavorable results:

- Non-military electronics industry and defense contractors will compete doggedly with ever increasing salaries for the inadequate supply of engineers. The high technology industry will become less competitive in world markets. Costs of defense will vastly exceed expectations.

- The faculty shortage problem will accelerate due to academia's inability to respond to the salary competition, "Crowding out" of faculty needs will occur.

. In addition to extreme cost overruns, the execution of defense programs will experience serious delays.

The engineering educators of the U.S. need help. There is need for complete awareness of the federal government and the Office of the President about the problem and the need for supportive fiscal and tax policies to solve it. At the same time industry associations must prepare to assist through programs to expand educational resources by increasing faculty and equipment. Industry-wide standards must be established for giving resources to engineering education.

Colleges, universities and governing bodies may have to adjust historical practices in order to accommodate assistance from industry to supplement conventional tuition and public sources.

In closing, I would like to quote Stephen Kahne, Director of the Division of Electrical Computer and Systems Engineering at the National Science Foundation (NSF).

> "It is no longer an open question whether the shortage of electrical engineers in the United States is or is not a crisis. It is. Sooner or later every U.S. industry dependent upon electrical engineering will be affected..and there are more such industries now than ever. Toy and automobile manufacturers, even textile and clothing companies, have discovered the value of electronics and computer-based systems in their products or manufacturing processes. Indeed, these new industries, previously unaffected by electrical engineering in any

significant way, are the hidden factor that invalidates traditional market surveys of future needs for EEs. It is hard to predict the growing need for electronics specialists in sectors of the economy that never before employed them."[17]

REFERENCES

[1]Ray Stata, President and Chairman, Analog Devices, Inc., "Needed:A Plan for Educating Engineers." Electronics, April 24, 1980, p. 26.

[2]"The Electronic Business 100." Electronic Business, February 1981 p. 64.

[3]Robert G. Gillespie, Vice Provost for Computing with Deborah A. Dicaro, Research Associate, University of Washington. Computing and Higher Education: an Accidental Revolution, 1981, p. 5.

[4]American Electronics Association, "Technical Employment Projections: 1981-83-85."

[5]National Center for Education Statistics, February 13, 1971, Bulletin NCES 81-406.

[6]Claudia Deutsch. Business Week, July 6, 1981, p. 105

[7]Catherine P. Ailes and Frances W. Rushing, "A Summary Report on the Educational Systems of the U.S. and the Soviet Union: Comparative Analysis." Prepared for NSF, SRI International, Final Report, March 1980, p. iii.

[8]Diane Conradson, San Jose State University Professor of Natural Science, and Walter Smithey, Curriculum Coordinator for Science and Math, San Mateo County Office of Education. Letter to Industry, January 1981.

[9]J. D. Kemper, Dean of Engineering, UC Davis, "Graduate Enrollments in Engineering; Meeting National Needs for Productivity," July 1980, p. 9. Source reference: Quarterly Unemployment Rates for Engineers Released, Engineering Manpower Highlights, Pub. NO. 225, Engineers Joint Council, New York, November 1972.

[10]National Opinion Research Center. Reported in Manpower Comments, May, 1981, p. 26.

[11]Roger Lowenstein, "Two-Edged Sword: Surge in Engineering Enrollment Begins to Ease Industry's Shortages but Stirs Trouble at Colleges." Wall Street Journal, August 20, 1981, p. 48

[12]Ward Worthy, "Chemical Education Falls on Hard Times." C & EN, February 9, 1981, p. 45.

[13]Stephen Kahne, National Science Foundation, "A Crisis in Electrical Engineering Manpower." IEEE Spectrum, June 1981, p. 50.

[14]Summary, Meeting of the Engineering Manpower Task Force, Business-Higher Education Forum, St. Louis, Missouri, April 7, 1981, p. 3. American Council on Education, Washington, D. C.

[15]Ibid., p. 46.

[16]Linda Goldstein, "Professors, Administrators Battle Over Faculty Pay Plan." San Jose Mercury, February 7, 1981, Section B1.

[17]Kahne. IEEE, Spectrum, p. 50.

Mrs. HECKLER. Thank you, Mr. Wellington. That is a very provocative, well-studied, and carefully researched paper.

It has some disturbing elements within it which we will develop and discuss as we go on.

Thank you for that very fine testimony.

Mr. Farrington, we would like to hear from you. I understand that you have served as the president and chief executive officer of Input-Output Computer Services since its founding in 1969. It is a pleasure to welcome you.

Mr. FARRINGTON. Thank you, Congresswoman Heckler and other members of the Committee on Science and Technology. It is a pleasure for me to have the opportunity to serve you.

I think it is very fitting that hearings be held on high technology here in Massachusetts and especially at MIT, which has provided this Nation with numerous innovations and high technology companies.

As the president of IOCS, Inc., a high tech company which was founded here in Cambridge, I am indeed pleased to have this opportunity to appear before this committee today.

It is my privilege to appear on behalf of the small business sector of the high tech industry.

At different phases in our national history, a combination of innovation and new technological developments have been the foundation for the continuing evolution of new industries, which have been the foundation of this Nation's economy.

Those industries, which certainly have included the automative, aerospace, consumer electronics, and many others, have served our economy well.

We have been recognized as the world leader in these areas, and our citizenry as a whole has enjoyed an unparalleled standard of living during the last half century.

Today when we speak of the high technology industries, we invariably think of the electronics, computer and computer-based industries.

In the chain of evolving industries, these are the ones that must serve our economy.

Our success in employing our population, in maintaining our standard of living, and increasing our competitive position in the world marketplace is dependent upon our success in our industries of today.

There are, however, a number of new and different variables that we must deal with today. These consist of foreign competition, lack of an adequate supply of trained human resources, financial resources, and the lack of appreciation for the critical role that small business has historically played in innovations and new technological developments.

My testimony will focus primarily on the role small business must play in the future and the needs for this segment of our free enterprise system in order for it to successfully carry out its role.

Approximately 97 percent of all U.S. business is considered small business. Accordingly, the existence of small businesses accounts for approximately one-half of private employment in this country and 43 percent of the gross national product. In order to comprehend the necessity and potential of progress in strengthening any

great society, it is necessary to recognize those stimulants and support areas which affect all facets of one's economy.

The Office of Management and Budget revealed in a recent study that from 1953 to 1973 almost one-half of all major U.S. innovations came from firms with fewer than 1,000 employees. Other supportive evidence relative to significant small business contributions is the 50 percent American economic growth which stems from technological innovations in technology according to the Senate Small Business Committee.

The National Science Foundation found that small high tech firms have been far more cost effective than larger companies when engaging in research, producing up to 24 times more innovation per research and development dollar.

According to a 1977 Office of Management and Budget study, small business firms have inadequate access to Federal research and development moneys. Seemingly, larger businesses with more than 1,000 employees use four times the number of research and development employees to develop and market the same number of innovations.

Yet small business' share of Federal research is still about the same as it was 4 years ago; namely, between 3 and 4 percent of the total Federal research and development effort.

The Job Generating Process, a study prepared in 1979 by Prof. David L. Birch of the Massachusetts Institute of Technology, was a widely represented sample consisting of 5.6 million businesses, which totaled 80 percent of all private sector employment.

The study concluded that small businesses with fewer than 21 employees created 66 percent of all new jobs in the private sector between 1969 and 1976.

Firms with 250 or fewer employees produced 90 percent of the 6.8 million jobs created from 1965 to 1976.

There are currently 12 Federal departments and agencies with research and development budget estimates exceeding $100 million in fiscal year 1982 that would be affected by legislation. Current legislation, such as the Small Business Innovation Research Act of 1981, attempts to strengthen the role of the small innovative firms in federally funded research and development; utilize Federal research and development as a base for technological innovation to meet agency needs, and to contribute to the growth and strength of the Nation's economy.

Smaller high tech businesses should and must play a vital role in this 4-year financial research and development phasing process aimed at fostering successful innovation of U.S. technology.

By maximizing our economic efforts, namely, smaller high tech companies, this minimal risk program will greatly enhance Federal objectives to promote progressive U.S. research and development projects.

H.R. 4326 and Senate bill 881 clearly express the need and importance of promoting smaller businesses in the high tech domain relative to research and development.

An important link necessary in commercializing research and development has not been utilized to its full capacity. These bills fill this gap by introducing the necessity of reviewing the technical

and economic feasibility of ideas proposed for technological advancement.

Supportive statistical evidence directs the U.S. attention to small businesses as the means by which our economy can overcome the current decline and uprofitable research and development spending resulting in consequent reduction in new technology.

High tech small businesses engaged in research and development are the essential links to do just this particular task.

What I have attempted to do is to bring before this committee the facts, which have been substantiated by Congress itself, that small business is vital to the overall goal of continued innovation and high technology development. Considering this, I feel that the House Science and Technology Committee should be as concerned about small business as a resource as it is about the human and financial resources and the challenge of foreign competition.

In perspective, small business is the seed from which innovation, high technology and evolving industries in this country are developed and upon which we base our free enterprise system; and without continued incubation of the seed, then all else eventually will expire.

For too long we have relied upon the Small Business Committees within the House and the Senate and the Small Business Administration to take the lead in advocating the development of small business in this country.

It is my feeling that our slippage in world markets has been due to a great extent to the lack of attention given to the seed of innovation and high technology, namely, small businesses; and without the proper attention by the Government as a whole and without giving the proper priority, then the slippage will continue.

Therefore, in closing I recommend that this committee consider the small business resources the same as the financing and human resources, that it, too, urges the passage and signing into law Senate bill 881 and H.R. 4326 and establish an ongoing process of monitoring the cultivation of high technology and small businesses for our future needs.

Mrs. HECKLER. Thank you. We realize in New England small business is a backbone of our economy. Your points are not only relevant nationally, but especially relevant in this region.

[The prepared statement of Mr. Farrington follows:]

Testimony for

COMMITTEE ON SCIENCE & TECHNOLOGY
OF THE HOUSE OF REPRESENTATIVES

by

Thomas A. Farrington

Input Output Computer Services, Inc.

November 24, 1981

It is very fitting that hearings be held on high technology here in Massachusetts and especially at M.I.T., which has provided this nation with numerous innovations and high technology companies. As the president of IOCS, Inc., a high-tech company which was founded here in Cambridge, I am indeed pleased to have this opportunity to appear before this committee today. It is my privilege to appear on behalf of the small business sector of the high-tech industry.

At different phases in our national history a combination of innovation and new technological developments have been the foundation for the continuing evolution of new industries--which have been the foundation of this nation's economy.

Those industries, which certainly have included the automative, aerospace, consumer electronics, and many others, have served our economy well. We have been recognized world leader in these areas, and our citizenry as a whole has enjoyed an unparalled standard of living during the last half century.

Today when we speak of the high technology industries we invariably think of the electronics, computer, and computer-based industries. In the chain of evolving industries, these are the ones that must serve our economy. Our success in employing our population, in maintaining our standard of living, and increasing our competitive position in the world marketplace is dependent upon our success in our industries of today.

There are, however, a number of new and different variables that we must deal with today. These consist of foreign competition, lack of an adequate supply of trained human resources, financial resources, and the lack of appreciation for the critical role that small business has historically played in innovations and new technological developments.

My testimony will focus primarily on the role Small Business must play in the future and the needs for this segment of our free enterprise system in order for it to successfully carry out its role.

Approximately 97 per cent of all U. S. business is considered small business. Accordingly, the existence of small business account for approximately one half of private employment in this country and 43 per cent of the Gross National Product. In order to comprehend the necessity and potential of progress in strengthening any great society, it is necessary to recognize those stimulants and support areas which affect all facets of one's economy.

The Office of Management and Budget revealed in a recent study that from 1953 to 1973 almost one-half of all major U. S. innovations came from firms with fewer than 1,000 employees. Other supportive evidence relative to significant small business contributions is the 50 per cent American economic growth which stems from technological innovations in technology according to the Senate Small Business Committee.

The National Science Foundation found that small high-tech firms have been far more cost effective than larger companies when engaging in research, producing up to 24 times more innovation per research and development dollar.

According to a 1977 Office of Management and Budget study, small business firms have inadequate access to Federal research and development moneys. Seemingly, larger businesses with more

than 1,000 employees use four times the number of research and development employees to develop and market the same number of innovations. Yet, small business's share of Federal research is still about the same as it was four years ago; namely, between 3 and 4 per cent of the total Federal research and development effort.

The "Job Generating Process," a study prepared in 1979 by Professor David L. Birch of the Massachusetts Institute of Technology, was a widely represented sample consisting of 5.6 million businesses, which totalled 80 per cent of all private sector employment. The study concluded that small businesses with fewer than 21 employees created 66 per cent of all new jobs in the private sector between 1969 and 1976. Firms with 250 or fewer employees produced 90 per cent of the 6.8 million jobs created from 1965 to 1976.

There are currently twelve Federal departments and agencies with research and development budget estimates exceeding $100 million in FY 1982 that would be affected by legislation, in addition to those with budgets in excess of $20 million. Current legislation, such as the Small Business Innovation Research Act of 1981, attempts to strengthen the role of the small innovative firms in federally funded research and development; utilize Federal research and development as a base for technological innovation to meet agency needs; and to contribute to the growth and strength of the Nation's economy.

Smaller high-tech businesses should and must play a vital role in this four-year financial research and development phasing process aimed at fostering successful innovation of U.S. technology. By maximizing our economic efforts, namely, smaller high-tech companies, this minimal risk program will greatly enhance Federal objectives to promote progressive U.S. research and development projects.

House Bill 4326 and Senate Bill 881 clearly expresses the need and importance of promoting smaller businesses in the high-tech domain relative to research and development.

An important link necessary in commercializing research and development has not been utilized to its full capacity. These Bills fill this gap by introducing the necessity of reviewing the technical and economic feasibility of ideas proposed for technological advancement. Supportive statistical evidence directs the U.S. attention to small businesses as the means by which our economy can overcome the current decline and unprofitable research and development spending resulting in consequent reduction in new technology. High-tech small businesses engaged in research and development are the essential links to do just this particular task.

What I have attempted to do is to bring before this Committee the facts, which have been substantiated by Congress itself, that small business is vital to the overall goal of continued innovation and high technology development. Considering this, I feel that the House Science and Technology Committee should be as concerned about small business as a resource as it is about the human and financial resources and the challenge of foreign competition.

In perspective, small business is the seed from which innovation, high technology, and evolving industries in this country are developed and upon which we base our free enterprise system; and without continued incubation of the seed, then all else eventually will expire.

For too long we have relied upon the Small Business Committees within the House and the Senate and the Small Business Administration to take the lead in advocating the development of small business in this country. It is my feeling that our slippage in world markets has been due to a great extent on the lack of attention given to the seed of innovation and high technology, namely, small businesses; and without the proper attention by the Government as a whole and without giving the proper priority, then the slippage will continue. Therefore, in closing, I recommend that this Committee consider the small business resources the same as the financing and human resources, that it, too, urges the passage and signing into law House Bill 4326 and Senate Bill 881 and establish an ongoing process of monitoring the cultivation of high technology and small businesses for our future needs.

Mrs. HECKLER. It is now a pleasure to call on Mr. McKay, executive vice president of the Foxboro Co., for his testimony.

Mr. MCKAY. Thank you, Madam Chairman.

I am pleased to be here to respond to your invitation.

We are headquartered in Foxboro, Mass. The Foxboro Co. generated revenues in excess of one-half billion dollars last year. We manufacture process-management and control instruments and systems used by the chemical, oil and gas, pulp and paper, power generation, food, drug, metals, mining, and other processing industries.

We employ more than 11,500 persons, approximately 7,500 of whom are located in the State of Massachusetts.

Our overseas business represents about 50 percent of total revenues. We believe that we are the worldwide leader in our industry.

However, I am painfully aware of the increasing levels of competition that continue to grow faster than increasing market opportunities in most areas of the world.

In my role as corporate director of technology, I am especially sensitive to the importance of technological leadership that is necessary to maintain a strong position in these world markets.

At present the U.S. Government, unlike the governments of most of the advanced and developing industrial countries of the world, does not have a positive, well-coordinated and comprehensive program to promote and encourage exports.

As a matter of fact, the Nation's export business has been used as a vehicle for achieving other national purposes, some of them mutually exclusive.

The result has been that trade has suffered but other purposes were apparently addressed to varying degrees of satisfaction or lack thereof.

Now, we are back to promoting trade and certain impediments standing in the way must be addressed.

As a result of the lack of a coordinated economic and trade promotion program, some disturbing trends emerge when one looks at the export performance of the United States as a whole.

One point looking up through 1979, the United States continues to suffer from a large and persistent trade deficit: $5.086 billion in 1976; $26.54 billion in 1977; $28.4 billion in 1978; and in 1979, $24.7 billion.

No. 2, the U.S. market share in manufacturing goods worldwide declined from 18 percent in 1960 to 11.8 percent in 1976.

No. 3, export from large sectors of U.S. industries, sectors such as automobiles, steel, and textiles, have all but disappeared and the volume of imports in these sectors has grown by leaps and bounds.

About the only bright spots of the U.S. export horizon are the R. &. D. intensive industries. These are high-technology companies, of which the Foxboro Co. is one.

From 1960 to 1979, R. & D.-intensive manufacturing industries increased their export surplus from $5.9 billion to $23.9 billion.

For the instrument industries alone, last year the exports exceeded imports by over $2 billion, a very favorable balance of trade.

At the same time, the trade balance on non-R. & D.-intensive industries declined from near zero to a negative $24.5 billion between 1969 and 1979.

We cannot, however, afford to be sanguine about the historically competitive performance of U.S. high-technology industries. Even industry segments on the cutting edge of technology are today facing serious competition from foreign countries which have developed strategies that include such things as aggressive export pricing, loan guarantees, sheltered home markets, and subsidized R. & D. as well as aggressively promoting capital formation, plant investment, and job formation through their tax policies.

Given this situation, it seems obvious to me that in formulating an overall U.S. export policy, particular and early attention should be given to the needs of those segments of the U.S. industrial base which are now performing well, but which will do less so unless their particular problems are addressed. There are three areas in this context that I will mention today.

These are DISC, Domestic International Sales Corp., provisions of industrial revenue bonds, and section 861(8) of the Internal Revenue Code.

In the case of DISC, this tax deferral provision is of value to high-technology companies of all sizes. Growth of exports is the objective and it is only beneficial if there is export growth over previous base periods.

I believe that Foxboro's experience with DISC is probably typical of U.S. companies with substantial export activities.

During the 1960's, the combination of dollar parities, foreign technical innovation, rising U.S. labor rates, and export incentives offered by certain foreign governments caused a serious leveling in our export business.

Then came legislation enabling us to form a DISC. We find that the DISC benefits help to defray the increased costs associated with export business and, therefore, allow us to maintain identical pricing in export and domestic transactions.

The competitiveness of these prices has enabled us to expand our exports significantly, consequently increasing our employment in the United States.

We believe if there had been no DISC, our U.S. employment today would be somewhere between 5 and 10 percent less than it is. Without DISC or some other form of export incentive, we would surely find it necessary to increase our export prices and, as a result, see our export sales and local employment seriously reduced. We consider DISC a valuable export incentive, not a subsidy. More important, we consider it an export stimulant.

Second, there are provisions of the industrial revenue bond regulations which, in fact, impeded the very purpose of the bonds.

The intent of the legislation is to provide sources of capital at lower cost to expand the industrial base of communities.

However, this source is closed to the most promising job-providing businesses because R. & D. expenditures are classified as capital expenditures even though they are expensed.

Also, R. & D. must be allocated to the factory where the product is manufactured, not where the R. & D. is performed.

Since the borrowing firm can invest no more than $10 million in capital expenditures over a 6-year period, 3 years before and 3 years following the date of borrowing, then the result is a penalty for R. & D.-intensive firms.

These are the very companies that provide the greatest opportunities for growth and expansion and, therefore, the greatest probability of increased numbers of jobs for those communities.

My third point addresses the repeal of regulation section 1.861(8) of the Internal Revenue Code. It is necessary to eliminate those provisions of our current tax policy which undercut our explicit national effort to encourage expanded R. & D. in the United States.

Section 861 presents a disincentive for firms with foreign operations to conduct their R. & D. activity here in the United States through a denial of domestic source deductions for all U.S. R. & D. expenditures.

This disincentive affects not only U.S. companies manufacturing abroad, but also companies exporting or leasing their products from the United States and providing customary services to foreign purchasers.

Action was taken recently to suspend this section for 2 years. We were pleased by this positive action and pleased that it was supported by Congresswoman Heckler, and now suggest that this revision be made permanent.

The combination of tax penalties and shortages of key technical skills—as my colleague from Massachusetts High Technology Council has mentioned this morning—in the United States has already resulted in the relocation of some of our R. & D. activities overseas.

We are not alone in this action and as long as penalties are in place for U.S.-based R. & D. activities, attrition of those activities will continue.

Analysts have long pointed to the positive, significant relation existing between an industry's commitment to R. & D. and its growth and profitability. That correlation also applies to an industry's performance in export markets. The relationship of export performance to innovation and research and development is neither mysterious nor obscure. All one has to do is to examine the list of products in which the United States enjoys a favorable balance of trade.

They are the same as those which have exhibited strong growth trends and possess the potential for continued strength.

They are high technology products and agricultural commodities. Both of these successes are the results of substantial and continuing commitments to research and development.

Such high levels of commitment are necessary for growth and in high technology businesses growth is requisite for survival.

To penalize the winners in the economically interdependent world in which we live increases the probability that they will become losers.

This is not wise policy. A wiser course is one that balances the opportunities for success of these R. & D.-intensive industries which promise so much return for our entire economy.

I believe the three issues which I mentioned, coupled with the necessary attention to the production of greater technical professional resources will insure that we realize those promises.

Thank you.

[The prepared statement of Mr. McKay follows:]

Good morning. I am Charles A. McKay, Executive Vice President of The Foxboro Company headquartered in Foxboro, Massachusetts.

The Foxboro Company generated revenues in excess of one-half billion dollars last year. We manufacture process management and control instruments used by the chemical, oil and gas, pulp and paper, power generation, food, drug, metals, mining and other processing industries. We employ more than 11,000 persons, approximately 7,500 of whom are located in the state of Massachusetts. Our overseas business represents about 50 percent of total revenues. We believe that we are the worldwide leaders in our industry; however, I am painfully aware of the increasing levels of competition that continue to grow faster than increasing market opportunities in most areas of the world.

In my role as Corporate Director of Technology, I am especially sensitive to the importance of technological leadership that is necessary to maintain a strong position in these world markets.

At present, the United States government, unlike the governments of most of the advanced and developing industrial countries of the world, does not have a positive, well coordinated and comprehensive program to promote and encourage exports. As a matter of fact, the nation's export business has been used as a vehicle for achieving other national purposes, some of them mutually exclusive. The result has been that trade has suffered, but other purposes were apparently addressed to varying degrees of satisfaction of lack thereof. Now we are back to promoting trade and certain impediments standing in the way must be addressed. As a result of a lack of a coordinated economic and trade promotion program, some disturbing trends emerge when one looks at the export performance of the U.S. as a whole.

1. The United States continues to suffer from a large and persistent trade deficit. $5.86 billion in 1976; $26.54 billion in 1977; $28.4 billion in 1978; and $24.7 billion in 1979.

2. The U.S. market share in manufacturing goods worldwide declined from 18 percent in 1960 to 11.8 percent in 1976.

3. Export from large sectors of U.S. industry - automobiles, steel and textiles - have all but disappeared, and the volume of imports in these sectors has grown by leaps and bounds.

About the only bright spots on the U.S. export horizon are the R&D intensive industries - the high technology companies like Foxboro. From 1960 to 1979, R&D intensive manufacturing industries increased their export surplus from $5.9 billion to $23.9 billion. For the instrument industries, last year the exports exceeded imports by over $2 billion, a very favorable balance of trade. At the same time, the trade balance on non-R&D intensive industries declined from near zero to a negative $24.5 billion between 1969 and 1979.

We cannot, however, afford to be sanguine about the historically competitive performance of U.S. high technology industries. Even industry segments on the cutting edge of technology are today facing serious competition from foreign countries which have developed strategies that include aggressive export

pricing, loan guarantees, sheltered home markets and subsidized R&D, as well as aggressively promoting capital formation, plant investment and job formation through their tax policies.

Given this situation, it seems obvious to me that in formulating an overall U.S. export policy, particular and early attention should be given to the needs of those segments of the U.S. industrial base which are now performing well, but which will do less so unless their particular problems are addressed. There are three areas in this context that I will mention today. These are:

1. Domestic International Sales Corp. (DISC) - This tax deferral provision is of value to high technology companies of all sizes. Growth of exports is the objective and it is only beneficial if there is export growth over previous base periods.

   I believe that Foxboro's experience with DISC is probably typical of U.S. companies with substantial export activities. During the 1960's the combination of dollar parities, foreign technical innovation, rising U.S. labor rates, and export incentives offered by certain foreign governments caused a serious leveling of our export business.

   Then came legislation enabling us to form a DISC. We find that DISC benefits help to defray the increased costs associated with export business and allow us to maintain identical pricing in export and domestic transactions. The competitiveness of these prices has enabled us to expand our exports very significantly, consequently increasing our employment in the U.S. We believe that if there had been no DISC, our U.S. employment today would be somewhere between 5% and 10% less than it is.

   Without DISC, or some other form of export incentive, we would surely find it necessary to increase our export prices and as a result see our export sales and our local employment seriously reduced.

   We consider DISC a valuable export incentive, not a subsidy. More important, we consider it an export stimulant.

2. Provisions of industrial revenue bond (IRD) regulations. The intent of IRD legislation is to provide sources of capital at lower cost to expand the industrial base of communities. However, this source is closed to the most promising job - providing businesses because R&D expenditures are classified as capital expenditures even if expensed. Also R&D must be allocated to the factory where the product is manufactured, not where the R&D is performed. Since the borrowing firm can invest no more than $10 million in capital expenditures over a six year period - three years before and three years after the date of borrowing - then the result is a penalty for R&D intensive firms. These are the very companies that provide the greatest opportunities for growth and expansion and, therefore, the greatest probability of increasing numbers of jobs for the communities.

3. Repeal of regulation section 1.861-8 of the internal revenue code.

Finally, it is necessary to eliminate those provisions of our current tax policy which undercut our explicit national effort to encourage expanded R&D in the United States. Section 861 presents a disincentive for firms with foreign operations to conduct their R&D activity here in the U.S. through a denial of domestic-source deduction for all U.S. R&D expenditures. This disincentive affects not only U.S. companies manufacturing abroad, but also companies exporting or leasing their products from the United States and providing customary services to foreign purchasers.

Action was taken recently to suspend this section for two years. We were pleased by this positive action - supported by Congresswoman Heckler - and now suggest that this revision be made permanent.

The combination of tax penalties and shortages of key technical skills in the U.S. has already resulted in the relocation of some of our R&D activities overseas. We are not alone in this action and as long as penalties are in place for U.S. based R&D activities attrition of those activities will continue.

Analysts have long pointed to the positive significant correlation existing between an industry's commitment to R&D and its growth and profitability. That correlation also applies to an industry's performance in export markets.

The relationship of export performance to innovation and research and development is neither mysterious nor obscure. All one has to do is to examine the list of products in which the United States enjoys a favorable balance of trade. They are the same as those which have exhibited strong growth trends and possess the potential for continued strength - high technology products and agricultural commodities. Both of these successes are the result of substantial and continuing commitments to research and development.

Such high levels of commitment are necessary for growth - and in high technology businesses growth is requisite for survival.

To penalize the winners in the economically interdependent world in which we live increases the probability that they will become losers. That is not wise policy - a wiser course is one that enhances the opportunities for success of those R&D intensive industries which promise so much return for our entire economy.

Mrs. HECKLER. Thank you very much, Mr. McKay. I appreciate your testimony which is very, very thoughtful.

I would like to ask Chairman Walgren if he has any questions.

Mr. WALGREN. Thank you, Mrs. Heckler.

I wanted to ask Mr. Wellington how he sees the contribution of Government and what might be contributed from the private sector in solving the larger manpower questions? I am relatively new to this area, and found myself supporting various programs in the Government that have put traineeships, fellowships and individual support in place, and through the NSF I understand we had about $90 million that was generally targeted toward engineering education per se in different capacities, $30 million in fellowships and then some other aid in curriculum development and some other aid in graduate traineeships and things like that.

Is that a significant contribution or is this problem really way beyond us as a government in terms of adding the resources, particularly with respect to instrumentation where we had a gesture toward increasing it, when you measure it against the breadth of the problem?

Somebody measured the problem at $20 billion and we were putting in $10 million.

How do you measure what the Government can do and what has to come from the society as a whole?

Mr. WELLINGTON. It is a difficult question to answer.

In this respect, however, I would say it is my understanding that the gentlemen who will be testifying from the university and college contingent here will be able to be more precise with regard to the recent budgetary considerations relative to the National Science Foundation.

I understand that the funds available have been severely reduced for the support of faculty and fellowships.

From the standpoint of industry—and I think I can perhaps address that more precisely—first, I do want to say that $90 million is not an insignificant amount of money. It is not enough to solve the problem.

The blue ribbon committee of the American Electronics Association has not been formed for the purpose of studying and simply throwing out a problem, but also to develop contributory programs toward a solution.

One that is being advocated amongst the membership—and there are 1,900 companies in the organization—is that the members of the industry specifically allocate 2 percent of their research and development funds to the field of engineering education.

That is many tens of millions of dollars. This is a new program that is being developed; however, in order for that money to become effective, we have a very complex problem.

As I alluded to, to the need from the academic community to adjust to the use of those funds, we have an educational community that is largely either privately supported or through State and local funds in its primary support, and the ability to adjust to infusions of capital or funds from industry would require also some adjustments.

For example, in some States tuition funds go into the general fund, so that if engineering tuition fees, for example, were either

increased or supplemented, the college administration does not necessarily have direct control over that.

There is the difficulty of fitting in adjunct teaching contributions from the graduate level people in industry that might be supported to do that because of the relationship of the accreditation of the schools when using some of those resources from the outside. So that, although industry—and I am speaking now of the electronics association in directing it toward the fact that only 4 percent of the graduates in engineering go into the electronics field today—is developing a program, it will be working at an awareness level at the State levels and at the local levels to bring about the underlying factors that will enable this money to be applied as efficiently as possible to the nature of this shortage.

As I said, the contributions from industry, the motivation for equipment, teaching equipment as opposed to research funds which the NSF has been particularly supportive of in the past, has been substantially helped by the recent Economic Recovery Act, the deductibility of the contributions of the product at its value in the marketplace; that is, 50 percent between cost and marketplace as opposed to before where one could simply contribute and receive a tax recognition at the cost of the material.

Therefore, it tended to cause old and obsolete material to be contributed. This is a very positive step from the resources standpoint, but from the faculty standpoint there is a much more difficult task in applying these funds that the blue ribbon committee is developing for our association.

Mrs. HECKLER. I see. I appreciate that. I am sure the others might continue on with that.

I wanted to ask Mr. Farrington, as I undestand it, this small business innovation effort provides a set-aside of 3 percent or something like that—a relatively small set-aside—for small business from Government agencies involved in a budget of x number of dollars for research and development.

Some university people have raised the problem with me that they feel this will move in on their territory or threaten their continued support.

I suppose there is sort of an instinct that set-asides or other efforts we make have to be justified on their scientific merit as opposed to who—that is, small business—is doing it; so the set-aside becomes a problem.

Have you had any discussions about that part of the bill yet and do you have any responses that would support the bill in that area?

Mr. FARRINGTON. I think, assuming that the R. & D. spending remains constant—which I would not like to assume—then the additional funding, grants, going to small business would have to come from some place from the amount of money that large businesses receive through R. & D. contracts or from universities.

I think the argument I would have is that there has to be some realinement because small business, relative to the role they have historically played, and must continue to play, is not getting its fair share of these R. & D. moneys.

So that would be my response to that, sure, you do have to look at R. & D. on a scientific merit basis.

I would not question that, but I think sometimes it is a matter of where do you spend the money. That is where I think we need the realinement.

Also, if you think in terms of the evolving industries, as I tried to point out, I think the computer industry is a good example of the key role small business has played when you compare that to the automotive industry. I think when Digital Equipment started in the fifties it served to make IBM a better company; also a more competitive company worldwide.

I think Datagen made that a better company. Apple will make them all better companies.

When you look at the $6 million in trade surplus in the computer industry, I don't think it is an accident that we have a lot of smaller businesses playing major roles there.

When you look at the automotive industry, if we had some means to get money to 10 other companies that make American bugs as opposed to the German bugs, I think we would have kept some of those industries in this country. That is the awareness that I am trying to make here today.

Mr. WALGREN. I wonder whether you wish the battle would not come so much between the universities and the small business sector, but rather the small business sector and the universities combined compared to what might be seen as large industry and the role that they play in the research area, which I am sure is substantial, and perhaps somewhat based on perhaps political influence at some point along the line of the larger corporations?

Mr. FARRINGTON. Well, I know of a number of good, large firms that do a lot of good things in R. & D. I have a lot of friends there.

What I would like to say is that I think we need to spend more money in R. & D. I think any business likes to think in terms of doing as much as they can. That is always a motivation.

But, if large businesses were beginning to think in terms of small business as a resource to them, and to their production capability, again I point to the automotive industry.

I do not think we would have had five other smaller automotive firms if they had had the production capacity of GM or Ford, and eventually GM or Ford would have taken many of those new innovations in production.

So I don't like to see a bout between the universities and small business and large business. I would like to see kind of an increased spending on the Government's part in R. & D.

Mr. WALGREN. Mr. McKay, can you talk a little bit about the degree of going overseas with R. & D. as opposed to doing the R. & D. here because of the Tax Code?

In Pennsylvania we are very sensitive to taxation too, and we think of ourselves as the State that has the most taxes, just as Massachusetts views itself, I guess.

There were some studies done for us in Pennsylvania by the chamber of commerce, and they came to the conclusion that as far as taxation was concerned, they did not feel that firms were making their decision whether to locate in Pennsylvania or outside Pennsylvania based on tax considerations.

I guess I am a little surprised that you take a whole operation overseas just based on that consideration and maybe you could give

us a little feel for what a balance sheet looks like in that area and how that decision is made and what kind of leverage do you get by doing that?

Mr. McKAY. I mentioned in my testimony that there were two major components to a decision to relocate R. & D. activities overseas. Those two major components were availability of technical professional skills—they are in short supply, particularly in southeastern Massachusetts at the moment—high demand, short supply.

Markets for those skills are more readily available in areas of Europe where we already have manufacturing locations. Therefore, we have supportive infrastructure for increasing or enriching our R. & D. activities there.

These are primarily located in the United Kingdom and in Holland, both of which have better markets, better supply of these technical professionals than we have at the present time in the United States.

The second factor is the penalty in the Tax Code regarding U.S.-based R. & D., which is used to offset the return on transactions overseas when that return is brought back.

That penalty is an insidious penalty.

In terms of balance sheet, P. & L., it depends entirely on what level of reinvestment a company makes in R. & D. and what level of foreign transactions he has and the return on those transactions.

In our own case, we have about 50 percent of our total revenue generated in overseas markets. It is a substantial amount.

In terms of our investment, we are investing about $30 million this year in R. & D., and this is reinvestment of company-generated funds. This is not sponsored research from Government agencies, the military, or anything of that nature.

I am now looking at about 10 percent of next year's R. & D. budget to be invested in activities located in these two sites overseas.

That will probably grow somewhat slowly, probably keep pace with the growth of my total R. & D. investments, thereby continuing to amount to about 10 percent of our investment being offered there because of these incentives, because of these two reasons.

I think the removal of penalties for R. & D. investment in the Tax Code is a proper direction to go, wherever it is found, and qualifying the leverage is a difficult thing because it depends on so many variables, but it is a good direction to go, and in this case I think, as Mrs. Heckler mentioned in her remarks this morning at coffee, she has talked with people in the industry here before casting her own vote for this action on section 861.

The quantitative value is difficult to assess without positing specific assumptions, but the direction is an extremely important one, and I think the concept is to avoid penalizing R. & D. investments based on the United States.

Mr. WALGREN. Thank you very much.

Mrs. HECKLER. Thank you.

Mr. Gregg.

Mr. GREGG. One of the big problems is how to maintain the educational system, especially in our secondary schools, as versus our postsecondary schools.

The statement was made that there is a 3-to-1 application-to-acceptance ratio for postsecondary schools. But in the secondary and junior high school, how do you keep teachers in place when they can be offered significantly more income if they are competent in their field.

In fact, if they are not even competent they can probably make more than they can make if they are teaching.

It seems to me you in the private sector are raiding the school systems, not necessarily intentionally, but as a function of the supply and demand system.

I would like to ask the panel individually suggestions you have to bring the school system up to a competitive position as far as maintaining teachers?

Mr. WELLINGTON. I will speak first.

First, I know in Massachusetts that we are making, as an industry, a significant contribution towards the retraining and the hiring of some of the redundant teachers to supply our needs, particularly in the computer science, programer, analyst field through education of the—for example—surplus of teachers that has developed for demographic reasons in the fields in English, social sciences.

You do bring a very important point to focus, Mr. Gregg, that the economic factors of the world are really derived from this shortage. The problem is substantially increased because of the inability to differentiate between compensation levels in the education system in most cases.

The compensation is more derived based upon level of education and tenure or time in place rather than the relative values in the marketplace of different skills.

That is one that industry cannot correct, but it must be faced. It is a reallocation of resources.

The long-term problem of the secondary and the junior high school level is, in fact, this scientific illiteracy trend that we have in this country, the prerequisites, the counseling of students.

Probably to some degree it is the reason that we have very many more people historically having gone into some of the nontechnical fields.

Their earlier counseling received may not have pointed out to them the opportunities that exist, not to in any sense degradate the legal profession, but we do have a much higher level of people going into those fields historically than into some of the shortage areas.

There is also a distinctly lower number of women who enter technical and scientific education programs, although studies have shown that at the third grade most girls have a higher mathematical proficiency than boys.

This is completely lost by the time they reach the high school level simply because of the sociological influences in their choice of educational paths.

This also is a counseling problem.

Mr. GREGG. Thank you.

Mr. FARRINGTON. I would like to speak to that in two parts.

First, in terms of maintaining the teacher or instructor base and, second, the applicant base.

No. 1 is the relation of teachers in the teaching profession. I will answer that simply by saying you have to pay more money.

The thing that suprises me is that there are as many instructors and professors in science and technology fields still within academia as we have. I am surprised they all haven't left, very frankly, because today when you look at just the economic side and the pressures to maintain the standard of living in this country, not to necessarily increase it, the costs are increasing very rapidly.

I think we have to find a way to have a compensation package for our instructors that is at least comparable and I would say even higher than industry because there are other factors that go into teaching that I know that I would have trouble dealing with, assuming that the compensation was the same.

On the other side, in terms of increasing the applicant base, one of the things that we are seeing now in high technology, especially in the computer industry, is the whole area of paraprofessionals.

That is the one where we have computer programers, people doing coding at a lower level that doesn't require that you have a master's or Ph. D. in engineering in computer science.

When we look around Boston, when we look around all of our cities, we see the unemployment among blacks and other minorities approaching 50 percent, especially at the younger ages.

I think that is certainly a resource that can be tapped. I think we solve two problems; one a social and economic problem related to the unemployed, and second, the need problem that industry has.

I know in the past some companies in this area, a lot of places, made some attempts at training. People tend to think that if things don't work a hundred percent the first time, they go away. That is not the approach we take in industry.

The approach we normally take, if it doesn't work 100 percent, you think of a better way of doing it; go back and make it succeed.

I think that is what we need to do to increase the applicant base.

Mr. McKay. My remarks would be similar to Tom's. I think the issues are seen both in issues of quantity and quality.

They are interrelated. The higher the quality, the greater the leverage. That is true for a professor, for a teacher in science, a member of the faculty of a university as well as it is true in industry in terms of a performer. I think the rewards for quality performance have to be commensurate with that performance and with the quality of the performance.

I think there is something to say there to the structure in our universities as well as something to say to industry and their support of such things through perhaps chairs and grants and other—fellowships, means of funding, higher salaries for quality teaching and also perhaps for government.

But there is a part for all of us to play. It would mean, in my judgment, a keener recognition of quality and greater differentiation of salaries as well as higher levels of salaries for teachers and professors.

Also, as Tom mentioned, there is a large area of support for paraprofessionals and other scientific personnel who could be educated through a change in structure of our educational system.

They could come from 2 year intensive technical schools, for example, as many States have already put in place. Then the issue of

quantity partially is served by that, but there is an issue of emphasis and that is a cultural emphasis—a cultural issue, I think.

I look at emphasis on science much as I do emphasis on economics, an all-pervasive subject for the future, yet we have cultural attitudes that relegates it to a dusty specialist kind of niche in our society.

I think one of my pet peeves when talking to my friends in the educational business is that curriculum enrichment to me means threading into the curriculum even social science courses the recognition of the importance of the bases of economics, science, and technology.

Less purity in the way, in my judgment, many social science and nonscientific oriented curriculum is based today. I think it is better recognized if it is inculcated into the general activity and started early.

The emphasis on marketable skills, on needs of the society and the culture, should be articulated early in grade school and high school. You do that, I believe, through articulating them to the teachers at those levels.

Mrs. HECKLER. Obviously there is no fast answer here.

I would like to address just a few questions to the panel.

Mr. Wellington, 10 years ago I was in this auditorium, which was the last prior experience I had here. It was a meeting totally different from this one, one in which the unemployed scientists of the area asked to meet with a Member of Congress who was concerned with the problem. I came at the invitation of Dr. Wiesner. It was a very touching experience for me and one in which I did not find ready answers forthcoming.

You have discussed the under-supply of engineers which is well documented. However, the current course of American policy, stressing a development of defense, would appear to draw upon the same engineering talent. For the next 4 years that will be one of the emphases and a priority of the Government.

However, should the priorities change, should the winds of public opinion shift in another direction, is it possible that we could cause an over-supply of engineers and then have a boom and bust syndrome repeated in Massachusetts, or is that impossible today?

If so, why?

Mr. WELLINGTON. Well, the total constellation of the electronics industry has changed vastly since 1970–71. The pervasiveness of the use of electronics coming from the integrated circuit has broadened tremendously in that period.

Now that does not, of course, remove the possibility of temporary dislocations. As I said in my statement, the total unemployment in engineering in that period to which you referred did not exceed 3.2 percent, but regionally, such as New England, it was a substantial problem until the process of relocation took place.

As a member of the engineering profession, we are not used to being unemployed. The effect at that time was traumatic. With the return of the military expenditure level to approximately what it was in the period of the sixties, or lower actually, leaving out the Vietnam period, will be much more difficult in this present time because that memory exists.

But I see no risk whatsoever apart from possible dislocation problems of an engineering surplus being developed. The gap is too large.

Mrs. HECKLER. Can the under-supply be addressed through continuing education of those who did leave earlier and have chosen other occupations in the interim? Can they be attracted into engineering? Is it desirable to do so?

Do we have the capacity in our universities to re-educate these people to make them productive to meet what is—seems to be a very serious under-supply situation to them?

Mr. WELLINGTON. First, I don't think we have the capacity, although there is the possibility for better application of the type and the development of types, as Tom has referred to them, as paraprofessionals.

There is a historical tendency in American industry to treat engineers a bit in an apprentice type of atmosphere; the new engineer out of the university may not be as efficiently used as he should be.

I think industry, through the process of the supply/demand relationship, has to address that.

The universities can contribute a lot by making it possible to have full degree, part-time programs and some of the universities in this area do that; others do not.

California has been very aggressive in that regard. Stanford University, for example, has that type of a program. That is a way to increase the supply and at the same time making people available in industry.

The most serious problem though, I believe, will be this superimposition of demand which has not been properly documented and projected onto a very broadly spread electronics industry.

Mrs. HECKLER. At the moment it seems that we have been sheltered in Massachusetts from some of the more serious aspects of the current downturn in the economy by virtue of the growth in the high technology field.

Would you expect that to continue?

Mr. WELLINGTON. I believe we are very fortunate in New England in that respect. Although the production levels are lower in terms of growth, there has not been a total decrease as there has been in many areas. This is somewhat affecting the hiring rates of the people at the shop floor level.

In a net basis though, there has not been a decrease even through this whole period. In fact, it has been increasing growth rate somewhat slower.

However, on the technology side, I don't know of any company that is reducing its engineering force because that is the seed of our future.

Mrs. HECKLER. Would any other members like to respond to the question of how this current downturn in the economy is affecting high technology and what the prognosis for the next year is?

Mr. FARRINGTON. I think here in Massachusetts we have not seen the impact on employment and the need for manpower. I think if we have this continuity prolonged, I think there would be some—I certainly believe there would be some impact on hiring and possibly some impact on production.

Some of the service companies that service the larger manufacturing firms with professional talent, I would expect there to be some decline and possibly some layoffs.

I would expect any laid-off professional people to be picked up by the large firms because there is such a pent-up demand. Even my firm, which is a small business, has a tremendous need right now.

This is kind of a point where we are looking to pick up additional people.

Mrs. HECKLER. Your feeling is that the outlook is positive with certain caveats?

Mr. FARRINGTON. That is right.

Mrs. HECKLER. Mr. McKay.

Mr. MCKAY. I think in the event of a major persistent contraction, of course, we will see a reduction in the rate of growth of employment in our sector as well as other sectors.

I believe very strongly that there will be no serious erosion in the demand for technical professional people and that belief is rooted in the market dictated facts that a reaction on our part to improved short-term financial margins at the expense of investments in R. & D. will only make us highly vulnerable in the long term and that vulnerability has in it the seeds of loss.

We have to be as concerned about position—trying to increase, maintain market share—as we are concerned about financial performance.

So I don't see at this time a serious downturn in the activities in high technology industries.

Mrs. HECKLER. Your comments were primarily related to technical personnel. Would you make the same comment about blue collar workers on the production line?

Mr. MCKAY. I think it follows. If we lose market position in terms of the worldwide market, then all employment levels will be reduced in our industries.

If we maintain or improve market share than all levels of employment will increase in our industries. So it follows one from the other.

Mrs. HECKLER. Hopefully there will be no major contraction then. Obviously the opportunities in the marketplace in both defense-related high technology and in commercial high technology are very substantial. So, hopefully, the problems we are experiencing will be of short duration and not of deep impact. That, I would suggest, seems to be your current analysis.

I would just like to tell Mr. Farrington that the Senate has scheduled action on the Small Business Innovation Act for Monday and that the bill in the House will be considered by four committees; Energy and Commerce, Armed Services, Veterans, and our Science and Technology Committee.

As a result of your excellent testimony today, I am going to suggest you be invited to Washington. I think this should be shared with the full committee when the issue arises again.

Mr. McKay, thank you for bringing a new piece of equipment from the Foxboro Co. Would you tell us something about what this strange looking device accomplishes?

Mr. McKAY. It is strange looking with a high incident light on it. If you have an opportunity to view it in lower light or at a different angle, you will see that it is rather esthetically pleasing. The multiple reflections of the infrared beam are used in a gas cell. We call it a Miran 20 meter gas cell, Miran being a contraction for miniature infrared analyzer.

It is used for a measurement of gases for component of analysis, toxic vapors, or what-have-you. To give Tom a little moment of pleasure, that was a design which was innovated, invented in a small company which later became part of our company.

That is the way it goes. There is a good case to be made for the dynamics of innovation by small companies, and the necessary stability of exploitation by a company with more resources.

This is an example of this.

This, by the way, recently found use in measuring the *Columbia* upon its return, after its short journey, for the presence of toxic vapors.

Perhaps those of you who saw that landing on television recognized the three technicians in the space suits with the cart walking around the *Columbia* waving what appeared to be a wand at it.

They were not casting a spell. As a matter of fact, they were measuring for the presence of toxic vapors and that instrument was there, an instrument using that 20 meter cell.

Mrs. HECKLER. That is fascinating. I am happy to see that small business played a role in it. I think the issue of innovation has been brought home very clearly here. It seems that there would be no role for small business if not to provide innovation, since the large companies have already cornered the market on basic services.

I want to say that I understand that Augat also produced something that was used in the *Columbia* mission, isn't that the case, Mr. Wellington?

Mr. WELLINGTON. That is correct. We had microcircuit packages in *Columbia*. I just wanted to add in that comment about small business, small business has become larger business.

In the last 10 years we have grown fourteenfold.

I doubt if 10 years ago you were talking about your hearings here, I would suspect we might have not been too much larger than you are today, Tom.

There are futures also without becoming parts of large companies.

Mr. McKAY. The answer is to become a large company. It is a dictum that high technology businesses, regardless of where they start, must grow in order to survive. The market is a growing one. Contraction of market share means the loss of everything.

Mrs. HECKLER. Of course, the market offers the opportunity for employment. Whether one is employed at a small company or large one, that compensation is essential to all the business activity of the State.

The need for survival for a small business firm is a very clear one to all business.

I want to say to the witnesses that they have been an excellent panel. We would like the opportunity to submit further questions

to you in writing if you would be available for that. Thank you very much for your testimony.

I would like to call to the witness stand Charles Coulter, president, American Research & Development Corp.

Mr. Coulter will speak on the subject of the capital needs of business.

It is a pleasure to have you, Mr. Coulter. I understand you joined the American Research & Development Corp. as a vice president in 1970 and served as the president since 1972; that you were previously head of Honeywell's European computer operations and later a vice president of Boston Capital Corp.

We understand your public service on several boards of high tech firms, your service beyond that in management positions, and in a leadership position in your industry.

We look forward to your testimony.

TESTIMONY OF CHARLES COULTER, PRESIDENT, AMERICAN RESEARCH & DEVELOPMENT CORP.

Mr. COULTER. Thank you.

Madam Chairman, members of the committee, I do represent American Research.

I am president of American Research, which does not do research and development, but it does venture capital.

Congresswoman Heckler, you will be glad to know that a lot of the companies that we have supported are, of course, Massachusetts companies.

Some of the ones we have invested in include Teradyne and High Voltage; there is also a little company called Digital Equipment that we were connected with; Lexidata, Visual Technology, and on and on. Some 10 or 20 over the years we have been involved with in Massachusetts.

In discussing capital availability for this forum, I see three connected parts:

Of course, number one involves money, capital; second, the people who put the money to work, and third, the Government that allows a risk/reward environment to make the whole process happen.

First of all, the capital. Is it available? Well, there are various needs for capital, and in the case of the venture capital portion, where we are addressing innovative technologies and specifically the interest of the committee and for us here today, I feel that there is not only adequate, but at this point, more than adequate moneys.

In fact, as of today there are more moneys available, capital available, from the venture capital community than at any time in the history of our country. There is approximately $5 to $6 or maybe more billion total moneys that are currently invested in the venture capital field.

However, let's put that into perspective for a moment and see how it compares with other pools of capital. For example, this $5 or $6 billion of venture capital moneys must be compared with the pension moneys in this country, which is $600 billion, or even the money market funds that I think go up or down by $5 billion practically every week.

So it is not a vast amount, although I am certainly agreeable with the fact that $5 billion is an enormous amount of money. In the perspective of the overall capital in this country available for investments, it is a relatively small amount.

Currently, as I say, there is more venture capital funds available than at any time in history. There are also more venture capital firms that have been started in the past year than at any other period. In fact, I think something over $1 billion in new moneys has come into the venture capital world in the past 18 months or so.

Where is this money directed? I would like to make a distinction here for the committee. The venture capital companies who are truly responsible for so many of the innovative new companies that have come along in the United States direct their companies where there is a market where the driving force for investment is the market.

Put it this way: A venture capitalist is concerned, worried, scared, whatever you wish, when they see a product that is searching for a market; but if they find a market that is searching for a product, they like it. It is the people, the entrepreneurs, who find the market that is searching for a product. They then come up with the product. They find us. And that is where we start.

I want to emphasize that we, your venture capitalist, have a time limit. We are probably 10 years oriented. Most of the partnerships are 10-year partnerships.

In the first 3 years, that is where you are developing, new investments, the money is being put out and you hope to develop a new business and bring it into fruition. Between 3 and 5 years is the timespan to get all the partnership money out and have it working. Then there is only 5 to 7 years to get your return.

I am saying this to separate it from the problem of long-term goals for the country in terms of research and development. Venture capital money is most probably not directed into research and development. It is market oriented and right now has a technology orientation toward technology applications to produce and build a company during a relatively short period of time.

Moving to the next area which I mentioned previously—and I cannot overstress—is people. A venture capitalist is nothing without the entrepreneur. He is the heart of it. If there are no entrepreneurs, venture money does no good, there is nothing. People—the entrepreneur—are the basis of what makes everything work.

General Doriot who, for many years, was the head of American Research was the coiner of the phrase that he would much prefer a class A man with a class B product than the other way around, a class B man with a class A product. I think we all subscribe to that. I don't know of any of my colleagues in this field who don't. It is the entrepreneur that makes it all happen.

The third and absolutely integral part of the whole operation is why we are here today, namely the Government's role.

The Government must allow the process to happen, not to hinder it. It must allow for a risk-reward. If the reward gets too low, there is a problem.

I would like to refresh all of us—although I think it has been well documented, certainly by the Venture Capital Association—

what happens when that reward goes away. Around 1971-72, some $3 billion each year new moneys was going into small business. This is categorized as businesses of under $5 million net worth—not necessarily all high technology. That is the criteria. Something over $3 billion went into this criteria during the years 1971-72 and prior.

During this period, the tax laws became increasingly restrictive. In addition, there were increasing regulations on small business. What resulted was virtually a total halt in the United States of funding of small business. I believe in 1973, and 1974 the total amount of moneys that went into small business was less than $100 million. Only some 16 companies in 1974 were funded. These were companies under $5 million net worth—only 16. This became so apparent that, thanks to the Congress, the laws were changed in 1978. The result is today the reward is again working and the results are astounding. The country is abounding in new opportunities. In our 35 years of business, we have never seen as much activity.

This activity is shared by all the venture capital groups. Entrepreneurs are coming from our major corporations. They are leaving to start their own companies with innovative ideas. What we heard here earlier on the previous panel are good examples: people leave, know a market, develop a product, get money, build a business and then eventually they get absorbed into a larger corporation or like Digital Equipment, stand on their own.

Coming back to capital availability—it is available. It is not a formation problem, but more a distribution problem. I would like for a moment to discuss Japan. Much has been written about Japan recently. Perhaps to oversimplify it, the Japanese approach is one of a pluralistic society, ours is individualistic. They end up with a consensus. In the United States, we rarely get consensus. Good or bad is not the point. The result is the United States becomes fragmented. Our national purpose becomes fragmented. On the other hand, one knows exactly where the Japanese are headed, what industry they are after; what their priorities are. Money is made available through governmental sources; MITI is one of the best known ones. Their government objectives are clear.

We do not have it that way. In the R. & D. area, a vital area, this committee is looking at how to get and allocate money to do the best job for the country. I am suggesting that the more the Government can state definite goals, whether water conservation policy, basic engineering policy, the better. The businessman will then formulate their plans—the markets will have been identified and venture moneys will be available for the Government goals.

An example: The Government recently reviewed their problem of the large numbers of computers they have and the equal large number of computer languages, 468 I believe, used. A committee was formed to study the language problem. They recommended a reduction to seven.

The committee felt that even seven was too many; and recommended one. The process took about 2 years, but recently the one language was established—called ADA. Already we have had companies coming to us to take advantage of this policy. The fact that the Government decided on one language automatically creates

new opportunities. At the same time it will save money within the Government.

This is a good example of the kind of goal setting action where the Government can be extremely helpful. Business will follow, fall in behind the goal. The venture capitalists will play their part, and new businesses are created.

Thank you. That concludes my testimony.

Mrs. HECKLER. Thank you, Mr. Coulter. Your comments about only $5 or $6 billion reminds me of Senator Dirksen's statement. He said, "A billion here, a billion there, pretty soon it is real money."

Mr. Walgren?

Mr. WALGREN. Thank you, Madam Chairman.

This is an area that I don't know very much about. When you say there are $5 billion available for high technology or technology-related businesses, is it segregated that way, where there is *x* number of billion dollars in private capital for this sector and *x* for that?

How do you determine these universes?

Mr. COULTER. In the way that your question is phrased, the numbers would be something like $200 to $300 million immediately available; that is available in various venture capital funds not currently invested.

The $5 or $6 billion is the amount of moneys that is invested in what is considered by the National Venture Capital Association to be venture funded companies. In the case of Digital Equipment, ARD's investment was $70,000. Digital today is valued at something over $5 billion. The $70,000 is included, the $5 billion is not.

Mr. WALGREN. Are these venture capital firms that just specialize in technology-related efforts or is that the universe of venture capital firms?

Mr. COULTER. Not necessarily. It would include such venture capital companis as Narragansett Capital, which specializes more in leverage buy-outs; Franklin Corp. the same way. Probably 85 percent of the venture capital companies invest in technology-oriented companies

Mr. WALGREN. Would there be a substantial infusion in that area if, let's say the genetic engineering field started to really deliver profits? Would you find the $5 billion number going up substantially?

Mr. COULTER. Yes, it would. In fact, genetic engineering technology, as far as I know, has all been funded by the capital venture companies. For example, there is a new $40 million fund, an offshore fund backed by venture capital people in Europe as well as by some people in this country directed entirely into the genetic engineering field.

Venture capital companies have funded over 25 specific new genetic engineering biotechnology companies in the past 18 months alone.

Mr. WALGREN. Do you have, on the second subject, any suggestions for how we set these goals that we would like to see everybody pursue?

Mr. COULTER. What the Government has done since 1978 to assist venture capital activity has been excellent.

As I mentioned, we need people, the entrepreneur who can see a reward, so that he is willing to take the risk, set out on his own and go through the job of building a company. This is a difficult task. It is hard work, dedication. It is difficult on their families, difficult on them. There must be a reward.

Then there are also the investors. They must be able to see the return on their moneys in comparison to say a money market fund where it earns perhaps a fairly sure 18 to 20 percent. This must be compared to locking one's money up for a long period in a venture capital fund. However, the recent capital gains taxation has been a strong step forward. It clearly has initiated a change in venture capital climate.

The changes in regulations on small business and business in general has been an additional, helpful factor. The ability to reward your entrepreneurs and management and supervisory management with options is another help. This comes again to the risk/reward theme.

When nothing is happening in the way of new business activity, I think the world and the market is saying, hey, let's have a little bit more reward into the marketplace. Then the creative process will again take place.

Mr. WALGREN. Thank you.

Mrs. HECKLER. Mr. Coulter, I am very intrigued by your testimony. I think you made a most unique contribution. We haven't heard from venture capital specialists before. This is a facet of the whole development of high technology that does need more exploration on our part.

I am somewhat confused, however, by an article that I read in Business Week which suggested that there was a capital crunch for computer industries who are trying to streamline their operation and automate and that they were possibly scraping the bottom of their coffers; and this seems to contradict or be in contradiction to your testimony on the amount of available capital.

I am sure you can explain this difference. Would you, please?

Mr. COULTER. I will try to, Congresswoman Heckler.

The capital crunch that you mention in the electronics industry and computer industry, may probably relate to the costs of setting up a new semiconductor operation.

That, indeed, is exceptionally heavy. That is a world, I believe, best left to the companies that are good at it, that have the resources, the Motorolas, the IBM's, and so on. It isn't for a venture capitalist normally to start up. The venture capital community does not have the moneys to do the job.

One semiconductor line is, I believe, about a $6 million investment. That is beyond what a venture capital firm can do. On the other hand, the venture capital community raised the money to start the funding of Gene Amdahls recent computer company.

There are some big figures that come out of the venture capital community, but not the basic fundings for semiconductors or, for example, in the energy field, the production of solar panels. This is an area where the Government can be extremely helpful, where it is beyond the resources of the venture capital community to take an innovative idea and bring it to market.

Mrs. HECKLER. Does this suggest that the operational development of the computer industry, for example, requires a different type capital funding than your general investment would entail?

In other words—it sounds as if you invest in new ventures or ventures that are about to make a new breakthrough, yet what we are talking about in terms of the capital crunch in the computer industry really relates to updating the facilities of an ongoing operation?

Mr. COULTER. Absolutely. Very well said.

Mrs. HECKLER. There is a definition of venture in that case?

Mr. COULTER. Yes.

Mrs. HECKLER. I was quite surprised when Mr. Farrington testified. He is the first witness on behalf of small business who did not talk about a lack of capital. Every other small business witness I have ever heard in Washington or at field hearings such as this has always cited that as a key problem of the small business industry and the growth of small business.

Would you say that there is an availability for the capitalization is no longer an issue for small businesses in the high technology field; that their problems are perhaps not as great as they might be in other small businesses?

Mr. COULTER. My answer to that would be yes. I think there is the availability of capital. But again the problems are the availability of people—the entrepreneur and the Government's role in allowing the process to happen—that is the vital aspect. This has in the past been closed, as we know. With the door open, many funding opportunities exist. For example, the formation of R. & D. funds is a new source because of tax advantages to individuals. Considerable money has gone into R. & D. partnerships which, in turn, helps not only small business but also larger businesses. When someone says there is no money available for their idea, it really is the marketplace saying that their idea, or technology they are trying to bring out, does not have an economic basis. I believe, that the venture capital industry does indeed fund virtually every worthwhile idea that is passed through us.

Mrs. HECKLER. Thank you very much for very fine testimony, Mr. Coulter

Mr. COULTER. Thank you.

Mrs. HECKLER. I would like to ask Mr. Robert Henderson, the president of ITEK Corp, Mr. Robert Seamans, Henry R. Lure, professor of environmental and public policy at the Massachusetts Institute of Technology, and Mr. Kenneth Ryder, the president of Northeastern University, to come to our witness stand, please.

We are honored to have such a distinguished panel. We would like to ask you to proceed.

Mr. Henderson.

TESTIMONY OF ROBERT HENDERSON, PRESIDENT, ITEK CORP.; ROBERT SEAMANS, HENRY R. LURE, PROFESSOR OF ENVIRONMENTAL AND PUBLIC POLICY MASSACHUSETTS INSTITUTE OF TECHNOLOGY; AND KENNETH RYDER, PRESIDENT, NORTHEASTERN UNIVERSITY, ACCOMPANIED BY BARBARA BAUM

Mr. HENDERSON. I am chairman and chief executive officer of ITEK Corp. Having heard the previous three panelists, I should tell

you where we are located. It may add to your evaluation of what I am saying. We are the largest producer of radar warning and threat warning equipment for tactical aircraft. That facility is located in Silicon Valley.

We produce very high quality electro-optical and photo reconnaissance products. Our cameras took the pictures on Mars, and we do make these systems in Lexington, Mass.

I am sorry Mr. Gregg left and I am sorry to tell you this, Mrs. Heckler, but we produce photo typesetting equipment in Nashua, N.H.

I am testifying as a member of the high technology industry of Massachusetts. My testimony is lengthly. I would like to submit it for the record and discuss it in summary form.

Massachusetts ranks fourth in the Nation in high technology employment and first in the percent of manufacturing workers engaged in this industry. In the past 2 years the high technology industry has added 31,000 jobs in a time of rising statewide manufacturing unemployment.

Many of us, as has already been said, feel that the most serious impediment to the continued growth of our industry is the scarcity of engineering and technical help.

We are simply unable to find enough technically trained people to meet our requirements. Estimates of unfilled entry level engineering jobs in 1980 range from 17,000 to over 25,000 jobs.

The shortage is forcing the industry to focus on short-term issues rather than investing in long-term programs.

As a result, we are experiencing a narrowing of the technology gap between the United States and its industrial competitors. This is leading to our inability to maintain export markets as well as increase the flow of high technology products into the United States.

At a higher level, it raises questions about our ability to maintain a superior technology position for the defense of this country.

Other nations, especially those that are economic and political competitors, are apparently able to graduate more engineers than in the United States. It is well known, for example, that Russia, with a population slightly larger than ours, graduates three times as many engineers and that Japan—as has been mentioned before—a nation with half our population, graduates 5,000 more electronic engineers annually than we do.

What is even more telling, however, is that on a per capita basis, or the number of engineers per 100,000 people, the output of engineers in Czechoslovakia is twice that of the United States, Bulgaria three times, and East Germany four times our rate.

Admittedly these are not today's industrial competitors, but based on their proportion of college age people in engineering, they could very well be in the decades ahead.

The countries that have built up their engineering population have out-paced the United States in world markets. Between 1963 and 1977, Japan's share of the world trade in manufactured goods doubled while this Nation's share fell more than 70 percent.

Between these same years, productivity increased in the manufacturing industries of West Germany by 114 percent, in Japan by 197 percent, and in the United States by only 39 percent.

We simply cannot continue to let our technological base erode. Not only are we in danger of losing our present markets, but we could very well lose the major markets of the future. We stand on the threshold of a new and exciting era in technology, one that could be as important to our growth as that which we experienced in semiconductors and computers.

The development of the VLSI's, the marriage of communications and computers, the advent of robotics, the development of biogenics, all herald great opportunities for growth. It should be this Nation's objective not to lose to others the development of these technologies and the resulting economic gains.

Now, the engineering and technical manpower shortage we are experiencing is not a transient phenomenon. For the near term the stumbling block, as has been mentioned today, is our Nation's colleges and universities. Their engineering schools are operating above capacity. The shortage of professors and instructors in these schools numbers in the thousands, while the equipment available for teaching is obsolete or inadequate.

Much has been said about this aspect of the engineering shortage before the Science and Technology Committee. I am sure that my associates on this platform will continue to talk about it. However, I would like to discuss today the other aspect of this shortage, one that is even more serious because it is longer term.

I am of the opinion that if you look out into the period 1985 and beyond that through the good efforts of Government and the academic and industrial sector, that we will somehow increase the capacity of engineering graduates.

If you take that fact and look at also the demographics of a declining school population, you begin to get at the longer term problem that I see. This is the problem of our Nation's primary and secondary school systems which are apparently unable to prepare students that are willing or capable of continuing their training or education in technical subjects.

This is evidenced by the fact that the ratio of technical degrees to all degrees granted is lower in the United States than in most of the world's industrial nations.

Two reasons can account for this and they relate directly to this country's primary and secondary educational process: The quality of curriculum and educators. The declining quality of curriculum is reflected in the most common measure of academic aptitude. Scholastic aptitude test scores or SAT's, have been on the decline for over a decade, and the decline has been consistent regardless of the ever-increasing amounts of money in constant dollars that the American public has been willing to spend.

Today only one-sixth of all high school students take a junior and senior level course in science.

Only one-half of all U.S. high school students take a math course after grade 10, creating a need for one-half of all engineering freshmen to take math remediation.

Just 15 percent of all high schol students take a course in chemistry. Only 7 percent in physics. Our industrial and economic competitors do not make this mistake.

That students in industrial nations take more than those in this country is well documented. A Soviet secondary school graduate, for example, surpasses that of his American counterpart by 8 years of math, 4 years of physics, 3 years of chemistry, plus 4 years of other science courses.

Obviously their emphasis is on different areas. Another thing happens in our elementary grades. Until grade 6, both male and female students score about equally on standardized math tests.

From that time, females take fewer science and math courses than their male counterparts. By the 12th grade, according to a recent California study, female competency in math has declined to about half of that of males.

Today, although women make up approximately half of our work force, only 9 percent of our scientists and engineers are female and most of these are in the sciences.

As stated earlier, because of the higher level of secondary education in math and science, a substantially higher ratio of high school graduates in other countries go on to becoming engineers. In this country our children, because of a dearth in math and science, cannot really make the choice to study engineering even if they wanted to.

Most students simply do not take the prerequisite courses which would allow them to enter colleges. Even if they do, many need extensive remedial work.

As the college level, there is a shortage of math and science teachers in our Nation's public schools. A 1981 national study of estimated supply and demand of secondary science and mathematics teachers found that 16 of the 46 or 35 percent of the State science supervisors responding characterized the mathematics teacher supply situation in their State as a critical shortage.

In 16 others they said they had some shortage.

Unlike the college level, however, this shortage is apparently not caused by low salaries, but by an inadequate number of teachers trained in these subjects. The production of newly qualified mathematics and science teachers has slowed to a trickle.

Last year, for example, Ohio State University, the University of Nebraska, and the University of Minnesota each graduated only one newly qualified mathematics teacher.

The same is true for science teachers. A recent North Carolina study, for example, showed that fully 70 percent of their teachers who hold science certification are certified only in biology.

Only 52 percent of the teachers who taught science in grades 7 through 9 rather, were appropriately certified.

Almost 29 percent of the teachers who taught science in grades 7 through 12 had no science certification at all.

The problem also exists at the primary grade level. A recent national survey indicated that less than 10 percent of elementary school teachers felt qualified to each math or science at this low level. This is not surprising.

If the high school student is preparing to enter a teaching college, he or she will not be required to take substantial math or science courses.

Once in teachers colleges, without these preparations, a student selecting a math major or minor would again require extensive additional preparatory courses.

Since we are faced with declining school enrollment which will in itself limit the available number of students, we must increase the quality of the curriculum and teaching staff in primary and secondary schools.

It is only by this method that we can increase the percentage of high school graduates that are qualified to enter engineering schools.

Let me summarize. We have a three-dimensional problem.

First, colleges and universities are unable to meet today's demand for engineers.

Second, the curriculum at the precollege level does not require that students be proficient in math and science which leaves students unprepared to continue their education in technology.

Third, our elementary and high school teachers are not trained in enough quantity to teach technical subjects.

As has been mentioned previously, industry is attempting to work on these issues.

The American Electronics Association and the Electronics Industry Association on the national level, and the Massachusetts High Technology Council in this State are examples.

Some industrial companies have extensive programs under way, but the job clearly cannot be done without Government involvement.

It is difficult to suggest possible solutions that will not increase costs or add additional rules and regulations. However, some of both may be required.

A decision has to be made as to what are the priorities for the future well-being of this Nation.

The engineering and technical manpower crisis deserves a place very high on that list.

First, this country should have a national engineering policy, an expression of the Nation's commitment to that field.

It should include manpower objectives and a system for measuring against those objectives.

It should also address the issues of education and technology standards, information transfer, and cooperation between industry and schools.

Second, although funding to local educational agencies is being cut back and may be sent to the State for disbursement, the use of these funds should be tied to very specific national objectives and quality standards for teacher competency, uniform curriculum, and testing standards.

Third, since there is an increase in the number of foreign students entering our foreign schools each year and since almost 70 percent return to their homelands, Federal regulation should require as much as possible that these students pay full and actual education costs rather than have their education subsidized by the taxpayer.

Finally, the Federal Government should act as a coordinator between industry and education to bring them together to seek common grounds and resolve difficulties.

Some of the issues to be addressed might include the criteria for industry-sponsored programs which is an extremely sensitive area at many schools, methods to supplement science and engineering faculty salaries, and seeking ways to compensate schools for equipment necessary to graduate each student.

Other recommendations have been made to Congress over the past year to correct both the existing engineering shortage and the deterioration in U.S. education. Basically they have the same problem. Congress is strongly urged to address this issue now.

Thank you.

[The prepared statement of Mr. Henderson follows:]

FORECASTING NEEDS: THE HIGH TECHNOLOGY INDUSTRY

FIELD HEARINGS
U. S. HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

Chairman

Doug Walgren (D. PA)

Testimony by:

Robert P. Henderson
Chairman and C.E.O.
Itek Corporation
Lexington, MA

November 24, 1981
M.I.T., Kresge Hall
Cambridge, MA

89-542 O—82——5

I am testifying today as a member of the high technology industry in Massachusetts. Massachusetts ranks fourth in the nation in high technology employment and first in the number of manufacturing workers engaged in this industry. Fully 28 percent of our industry is classified as high technology.(1)

In the last two years, the high technology industry has created almost 31,000 jobs in Massachustts, (2) in the face of overall declining manufacturing employment. The question today is: Can this rate of growth or any rate of growth continue in light of present conditions?

There are a number of reasons for the question. Among them are the high cost of capital, increasing competition from overseas and the ability of the present market to absorb new products.

The most serious impediment to continued growth, however, is not a market or economic factor. It is the existing scarcity of engineering and technical help. The high tech industry is people poor. There are not enough technically trained people available to meet the requirements of this industry. The United States, unlike other nations, is seemingly unable to produce a sufficient supply of technically educated people. This has prevented many companies from expanding and adding to the economy. Overall, it is hurting our ability to maintain a technological edge in world markets.

Severity of Problem

The shortage is very real. The U.S. Department of Labor estimated that there were 17,000 unfilled entry-level engineering jobs in 1980; other estimates have been as high as 25,000.(3) There is no letup expected in demand over the foreseeable future. According to a recent American Electronics Association's Survey of its membership, representing about one-third of the total U. S. electronics industry, the anticipated demand for engineers in this segment of the high technology industry (Table 1) far exceeds the growth potential for colleges and universities (Table 2).

Much has been said about the reasons for the engineering graduate shortfall. They were discussed in at least two recent hearings before the House Science and Technology Committee.(4) Basically, the reasons given for the shortfall were: inadequate facilities at colleges and universities, facility shortages and the lack of up-to-date equipment for training.

These points need not be restated. It is more important to look at the implications of this shortage. They include the following:

- Shortfall in Employment. The New England Congressional Institute stated that as of

June 1980 over 5,900 jobs in Massachusetts high technology industry remained unfilled. (5) On an average, for each technical/professional job filled in this industry, an additional three to five support and administrative personnel are required. To this must be added 7.4 jobs in the non-manufacturing sector which are created for each 10 new manufacturing jobs.(6) The total employment shortfall to Massachusetts could have been as high as 40,000 jobs or just under 25 percent of the State's current unemployment figure.

- Economic Impact. The loss in personal income as a result of the Massachusetts employment shortfall is substantially over half a billion dollars.

- Small Business Impact. Small companies create the majority of new jobs. David Berg of M.I.T. determined that 80 percent of all new jobs came from firms with fewer than 500 employees.(7) These firms are today's innovators, yet they suffer most from the engineering shortage (Table 3).

But the shortage causes all high technology companies to suffer. Any company, faced with the necessity to deliver on today's programs and solve today's problems, utilizes maximum human resources to produce what is needed immediately. Therefore, engineers are not available for advanced development or process

improvements. Innovation and productivity suffer. The effect causes serious implications for the long term by narrowing the "technology gap" between the U.S. and its international competitors.

Moreover, we reduce our ability to compete against foreign competition. If this state of affairs is allowed to continue, high technology imports will increase and the one bright spot in today's U. S. economy will go the way of automobiles, TV sets and shoes.

Other nations, especially those that are economic and political competitors, are apparently able to graduate more engineers than the United States. It is well known that Russia, with a population just slightly larger than ours, graduates three times as many engineers and that Japan, a nation with half our population, graduates 5,000 more electronic engineers annually than we do.(8)

What is even more telling, however, is that, on a per capita basis, the output of engineers by Czechoslovakia is twice that of the United States; Bulgaria is three times and East Germany is four times our rate (Table 4).

Admittedly, these are not today's industrial competitors. But, based on their proportion of college age people in engineering, they could very well be our competitors in the decades ahead.

The countries that have built up their engineering population have outpaced the United States. Between 1963 and 1977, Japan's share of world trade in manufactured goods (excluding fuel and food) increased from eight to 15 percent while the United States' share fell from 21 to six percent. Between these same years, productivity increased in the manufacturing industries of West Germany by 114 percent, of Japan by 197 percent, and of the United States by only 39 percent. (9) For the last two years, a zero productivity gain has been reported in this country.

If the U.S. had maintained its 1963 productivity rate until the present time, the United States would have been able to afford the Carter Budget, the Reagan tax cuts and been able to give a substantial cash grant to every man, woman and child in the United States. (10)

Duration of Shortfall

The duration of the engineering shortage is disputed. Some sources claim a surplus of BSEE's by 1990. (11) Others claim the shortfall will reach 300,000 by that time. (12)

The truth probably lies in between, but the general concensus in the high technology industry is on the side of a continued shortfall even though engineering degrees have increased over the past four years. (13)

There are reasons for this pessimism other than the fact that there is a limit as to how far existing, over utilized, colleges and universities can expand

without a mass infusion of funds.

The principal reason is the anticipated expansion of the high technology industry. Some examples of this expansion are:

- The dawning of the first VLSI's will herald a new information technology product demand explosion which will equal or exceed the growth curves of the computer industry.

- The marriage of communications and computers will bring forth an entirely new industry to the American scene.

- Increased defense spending, and the need for new, even more sophisticated weapon systems, will significanly add to engineering demand.

- Emerging fields, such as robotics, and the need to increase productivity will create new, specialized engineering fields.

- The increasing complexity of each additional engineering advancement in ongoing technologies will increase the numbers of engineers required to maintain continuing programs and products.

Other reasons for pessimism include the fact that there are indications that there will be a significant decline in the number of degrees granted in the next

few years and that the peak we are now experiencing will decline (Table 2).

In addition, an increasing portion of the advanced engineering degrees granted in the United States go to foreign nationals (Table 5), the majority of whom do not remain here after graduation.

As bad as the engineering shortfall is, the situation for technicians (Table 6) and skilled workers is even worse. It has been estimated by 1990 that the country will need over 10,000 tool and die makers, 11,000 drafters, 23,000 engineering technicians, and 58,000 machine service technicians.(14)

Against these needs we are faced with a declining school enrollment (Table 7). A viable supply of engineers, technicians and skilled workers is just not on the horizon.

Concerns with Basic Education

A primary reason for this upcoming shortfall lies in our nation's primary and secondary school systems. This country does not adequately prepare students that are willing or capable of continuing training or education in technical subjects. This is very evident since the ratio of technical degrees to all degrees in most other industrial countries is much higher than ours. (Table 4).

Two reasons can account for this that relate directly to the country's primary and secondary educational process -- the quality of the curriculum and educators.

The declining quality of the curriculum is reflected in the most common measure of academic aptitude. Scholastic Aptitude Test Scores, or SAT's, have been on the decline for over a decade, and the decline has been consistent, regardless of the ever increasing amounts of money, in constant dollars, that the American public has been willing to spend (Figure 1).

Excuses given for the decline include the fact that a greater percentage of students are taking the test or that the expectations of today's parents are not high. Others discount the test as not being meaningful.

There is another more realistic premise. Students leaving our high schools are less prepared in the basics than previous generations of Americans.

Only one-sixth of all high school students take a junior and senior level science course. Only only one-half of all U. S. high school students take a math course after grade 10, creating a need for math remediation by one-half of all entering college freshmen. Just 15 percent of all high school students take a course in chemistry -- only seven percent in physics (15).

The 1980 presidential report on science and engineering education concluded that "more students than ever are dropping out of science and mathematics courses, and this trend shows no sign of abating." (16) We now rank fourth in scientific literacy behind the Soviet

Union, West Germany and Japan.[17]

Students opt for the easy way. A listing of the popular courses in a typical Massachusetts high school include such offerings as "Teenagers and the Law", "Crime and Society", "Personal Consumer Education", and "Child Behavior". [18]

This country simply must challenge its students more. But how? State Boards of Education are no help. To graduate from a Massachusetts high school, state requirements are that a student need pass only four years of English, one year of American History and four years of Physical Education.

And when math and science courses are taught, there are no common standards for evaluation. Local communities can, on their own initiative, vary the passing score on state achievement tests to "improve" the image of competency. [19]

Our national government offers no encouragement, either. To this day there are areas within the Federal Government insisting that declining achievement scores cannot be attributed to a lessening of the study of mathematics and science.[20] What is not said by the U. S. Department of Education is that present day offerings of math courses include such areas of study as "Consumer Math", "Math Review", "General Math" and "Financial Investment",[21] courses unheard of two decades ago.

Our industrial and economic competitors do not make this mistake.

- In Russia, albegra and geometry begin in grades seven and trigonometry is added in grades eight through 10. All Russian students complete five years of physics, four years of chemistry, and one to four years of high school biology.

- In West Germany, biology is introduced in grade three, physics and chemistry in grade five and an increasingly advanced math and science course added each year of high school.

- In Japan, 25 percent of all class time in grades seven to nine is spent on math and science, with trigonometry added in grade nine. Thirty-three percent of all Japanese high school students take three natural science courses and fourth math courses. Japanese 13-year olds have the highest math achievement scores amongst 12 industry countries, including the United States. (22)

The results are evident. Whereas in the United States, 75 percent of our children complete high school, that percentage is 98 percent in Russia and 92 percent in Japan. And, unlike in the United States, there apparently is very little dispute in those two countries over the quality of education. (23) (24)

Another thing happens in our elementary grades where the teaching process plays a role. Until grade six both male and female students score about equally on standardized math tests. From that time on, females take fewer science and math courses than their male counterparts.(25) By the twelfth grade, according to a recent California study, female competency in math has declined to 51 percent of that of their male counterparts.(26) Today, although women make up half of our workforce, only nine percent of the science and engineering workforce is female and most of these are in the sciences. (27)

Whereas a substantially higher ratio of high school graduates in other countries go on to become engineers, our children, because of a dearth in math and science courses, do not even have the choice to major in these fields -- even if they wanted to. Most students do not take the prerequisite courses which would allow them to enter engineering colleges. And even many of those that do take the prerequisites need remedial work.

Michigan Technological University, primarily an engineering school, requires four years of high school math for admission at its School of Engineering. The school gives a math placement test to incoming freshmen, and finds that every year about one-third of the students need remedial algebra, remedial trigonometry, or both, to be able to take calculus, the first-year math course for an engineering major.

Dr. Clyde Work, Dean of the Engineering School who has studied math deficiencies in incoming engineering freshmen, finds that every year nationwide, thirty to forty thousand students enter engineering schools unprepared for calculus. (28)

At Iowa State University, entering students must have graduated in the upper half of their high school class; out-of-state students in the upper quarter. Although their engineering school is selective and overcrowded, only one-third of this year's entering freshmen in engineering qualified on the placement test to take calculus. One-third need a remedial course in algebra; the remaining third need remedial trigonometry and pre-calculus. (29)

Ohio University has complete figures over a period of time on entering freshmen in general undergraduate programs, as opposed to those students who met the University's higher standards for admission to the engineering school. Their Student Advancement Center teaches pre-algebra to about one-third and remedial English to one-sixth of the entering freshmen. (30)

Primary and Secondary Teaching Quality

This problem is either caused by and/or aggravated by teaching staff quality.

As there is at the college level, a shortage of math and science teachers and certified instructors also

exists in our nation's public schools. A 1981 national study of estimated supply and demand of secondary science and mathematics teachers found that 16 of the 46, or 35%, of state science supervisors responding characterized the mathematics teacher supply situation in their state as a "critical shortage"; 16 others said they had some shortage. (31)

Unlike the college level, however, this shortage is apparently not caused by low salaries but by an inadequate number of teachers trained in these subject. The production of newly-qualified mathematics and science teachers has slowed to a trickle. Last year, for example, Ohio State University, the University of Nebraska, and the University of Minnesota each graduated only one newly-qualified mathematics teacher. (32)

This is not surprising. If a high school student is preparing to enter a teaching college, he or she will not be required to take substantial math courses. In a teacher's college, without this preparation, a math major or minor would require extensive additional courses.

Let me use my state as an example. Massachusetts state colleges offer an education major for prospective elementary school teachers which is centered around courses in pedagogy and child development. Other required courses reflect an

attempt to cover basic skills and knowledge, i.e., English composition, but the requirements for math and science are appallingly low. Only the University of Lowell requires two years of general science. Other state colleges require only 15 hours in the math and science area and these can include courses such as "Review of Basic Arithmetic" and "Instructive Geometry". The average SAT's for students for each section in the University of Lowell program is 400; 380 at other state teacher colleges.(33) Certification is almost automatically granted to anyone who graduates. As bad as this is, this certification can be used to teach in middle and junior high schools.

The change from "the basics" to "innovative curriculum" apparently coincided with a decline in teacher qualification. A recent national survey indicated that less than 10 percent of elementary school teachers felt qualified to teach math or science at this low level.(34)

The situation for the secondary teachers is, if anything, worse. Massachusetts state teacher colleges, without exception, require potential secondary teachers to major in a regular field in the liberal arts, involving 30 semester hours concentrated in the major. Education courses, including the practicum, count toward graduation but education is no longer a separate major.

In addition to the liberal arts major, twelve semester hours in education are required plus 18 semester hours (1.5 year-long courses) in the academic field in which the teacher is to be certified, if that certification is to be obtained in a non-liberal arts subject.

These requirements are absurdly minimal. Consider the implications. Any state college graduate with a liberal arts major can receive certification not only for that field but for math merely by taking 18 semester hours of courses in such subjects as a "Review of Basic Arithmetic" and Instructive Geometry."

Inadequate teacher preparation manifests itself in other areas besides math. Juniors and seniors representing a random mix of all students, tested for enrollment in a Personal Reading Improvement program at Fitchburg State College were found to have reading comprehensive scores equivalent to grade 10.8. (35)

The problem is not limited to Massachustts. To cite one example: A recent study in North Carolina shows that fully 70 percent of their teachers who hold the science certification are certified only in biology. Only 52 percent of the teachers who taught science in grades seven to nine were appropriately certified. Almost 29 percent of the teachers who taught science in grades seven through 12 had no science certification at all. (36)

The situation is apparently getting worse. From 1972 to 1980, the decline in SAT scores for education majors, nationwide, was over twice that of all undergraduates.(37)

Effect of Non-School Factors

That teaching quality, rather than non-school factors, is a leading culprit in the decline in achievement scores seems an unavoidable conclusion.

At the elementary level, where basic skills are taught, a surprising break in the overall national pattern of dropping achievement scores emerges.

Whereas SAT scores, as well as achievement scores in reading and math have declined persistently since the mid-sixties, achievement scores in grades one through three have remained stable.

The implication seems to be that, far from being responsible for dropping achievement, students' home environments and parental expectations sustain them through the early years of schooling. It is during these early years that parental control and influence are undoubtedly strongest.

The national drop in achievement scores does not begin until about the end of the fourth grade. Thereafter, it increases, not only for individual

89-542 O—82——6

students but persistently and markedly throughout entire grades. Ironically, the highest percentage of loss in achievement occurs in the top 25 percent of students -- those whose home environment would normally be expected to be most favorable to academic success.[38] (Figures 2,3)

Comparison of absolute raw scores of elementary pupils of the late 1930's with the raw scores of 1950's school children on the same test shows that 1930's school children scored significantly higher (Tables 8, 9); and SAT scores in the 1950's were substantially higher than they were in 1981.

Public school classes of 30 to 40 children were not uncommon in the 1930's and about half of the children in large cities came from non-English-speaking backgrounds. During those depression years, poverty touched many more public school students than it does today's youngsters, even in inner city schools.

The implication here is that today's lower achievement scores cannot be blamed on lack of funds (Figure 1) or class size (Figure 4). Nor, apparently, can they be explained by socio-economic background.

The International Evaluation of Educational Achievement (IEA) is a ten-year study which compared the results of schooling in nineteen countries. "After

the socio-economic background of the students has been taken into account, students are still remarkably different in their academic performance, with about 90 percent of the variance in their test scores still remaining to be explained by other factors," the study concluded. (39)

While noting that these other factors may be even more sensitive measures of socio-economic status, even if socio-economic variance were doubled to 20 percent, that would still leave 80 percent unexplained. To quote the study further, "In the IEA studies, school qualify variables turned out to have substantial influence on achievement, and some analyses produced the finding that school quality was 'of equal or of even greater importance than the home background of the child.'" (40)

This is not to say that there are not good school systems or good teachers. There are.

It does indicate that undertrained, thus underqualified, teachers, along with a soft curriculum, have played a major role in the decline of educational standards in this country.

Reason for Improved Technical Education

There has been a serious deterioration in the teaching of math and science in our basic educational system.

On a very elementary level, this has resulted in today's most common phobia in America, technophobia. (41) At the highest level, it is threatening the economic and political leadership in the United States.

There is a need for everyone to have an educational background in technology so that those who do not become scientists or engineers can make informed decisions about the nation's technological goals and objectives.

And for those who choose not to go to college, the increasing technical complexity of the workplace favors the employment of youth with a firm understanding of math and science. Without this background, it is difficult to enter training programs for technicians and skilled workers.

Those high school graduates wishing to enter engineering schools are finding themselves unqualified. Without a comprehensive background in math and science, they choose careers for which there are no jobs. Thus, our educational system has become a prime cause of this country's employment imbalance. And, without sufficient technical manpower, we will not be able to maintain our slim leadership in worldwide high technology markets or to develop the sophisticated defense systems of the future.

Recommendations

At a time when there is an ongoing debate about the future of the U.S. Department of Education

and when funding is being cut and turned over to the states, it is difficult to suggest possible solutions to the engineering crisis that will not increase costs. It is also difficult, at a time when many educators believe that the government has become a surrogate Board of Education, to suggest additional rules or regulations.

However, some of both may be required. A decision has to be made as to what the priorities are for the future well-being of this nation. The engineering and technical manpower crisis deserves a place high on that list. I would offer the following five recommendations.

First, this country should have a national engineering policy -- an expression of the nation's commitment to that field. It should include manpower objectives and a system for measuring against those objectives. It should also address the issues of educational technology standards, information transfer and cooperation between industry and schools.

Second, although funding is being cut back and may be sent to the states for disbursement, the use of available funds should be tied to very specific objectives and quality standards. For example:

- Funds spent for a variety of training activities aimed at teachers and administrators should be directly related to minimum nationally

established teacher competency criteria and curriculum requirements.

- Grants to local schools, such as those made under the new Federal Education Consolidation and Improvement Act, should be directed to improvements in basic education at the primary and secondary level. Minimum course requirements and competency tests should be established at the national level.

- Federal standards regarding curriculum and competency should also be established for vocational schools, two-year community and teacher colleges, if they receive federal funding.

- Although quality standards are recommended, it is also suggested that current federal regulations for schools in the non-scholastic area be reviewed for significance and, where found unnecessary, removed.

Third, since almost 70 percent of foreign students learning in this country return to their homeland, federal regulations should require foreign students to pay full and actual educational costs rather than having their education subsidized at the expense of the U. S. taxpayers and students.

Fourth, the recently enacted 25 percent tax credit for equipment donations to universities apparently was restricted to gifts for use in research in the

physical sciences. This Act should be extended to include equipment donations for engineering and technical teaching applications.

Finally, the federal government should act as a coordinator in bringing industry and education together to seek common grounds and resolve difficulties. Some of the issues to be addressed might include:

- establishing criteria for industry-sponsored research laboratories and their involvement in commercial products;

- determining methods to supplement facility salaries;

- obtaining agreement on ways to compensate schools for the estimated $1500 in equipment necessary to graduate each student, such as a fee charged for each graduate hired, which would be used to replace equipment.

Other recommendations have been made in Congressional hearings over the past year to correct both the existing engineering shortage and the deterioration in U. S. education. Basically, they are the same problem. Congress is strongly urged to address this issue now.

BIBLIOGRAPHY

(1) "High Technology Employment in Massachusetts and Selected States", Massachusetts Division of Employment Security, Commonwealth of Massachusetts, 1980.

(2) Alex d'Arbeloff, Massachusetts High Technology Council Membership Meeting, November 4, 1981.

(3) Curtiss J. Thomson, "The Crisis in Engineering Education," West Virginia University Alumni Magazine, Summer, 1981.

(4) "Survey of Science and Technology Issues, Present and Future," Committee on Science and Technology, June 1981, and "Engineering Manpower Concerns," Committee on Science and Technology, October 6, 1981.

(5) C. Staelin and B. Spencer, New England Congressional Causus Memorandum dated April 9, 1981.

(6) Associated Industries of Kentucky, Research Department Study, September 1980.

(7) Fred A. Tarpley, Jr., Office of the Advocacy, Small Business Administration, "Domestic Policy Review of Industrial Innovation and Recommendation for Creating Jobs through the Success of Small Innovative Business," United States Technical Policy.

(8) Engineering Manpower Commission, January 1979.

(9) Ibid.

(10) Joseph Wright, Deputy Secretary oc Commerce, Presentation before NIRI, November 5, 1981.

(11) Hufstedler and Langenberg, "Science and Engineering Education for the 1980's and Beyond: A Report to the President." NSF-DOE, October 1980.

(12) Electronic Engineering Times, Monday, December 8, 1980.

(13) Ibid., "Survey of Science and Technology Issues, Present and Future."

(14) James Campbell, U. S. Chamber of Commerce Representative. Testimony before the Senate Labor Committee's Employment and Productivity Subcommittee, June 15, 1981.

(15) Ibid. "Survey at Science and Technology Issues, Present and Future."

(16) Ibid.

(17) Diane Conradson, San Jose State University Professor of Natural Science, and Walter Smithey, Curriculum Coordinator and Science and Math, San Mateo County Office of Education. Letter to Industry, January 1981.

(18) Billerica, Massachusetts High School Catalog, 1980-81.

(19) Robert G. Lee, Blue Hills Regional High School. Letters to the Editor, Boston Globe, November 9, 1981.

(20) M. D. Eldridge, U. S. Department of Education, Press Release, August 3, 1981.

(21) Burlington, Massachusetts High School Catalog, 1981-82.

(22) Ibid. "Survey of Science and Technology Issues, Present and Future."

(23) U. S. News and World Reports, July 28, 1980, page 50.

(24) Michael Kirst, "Japanese Education: Its Implications for Economic Competition in the 1980's." Phi Delta Kappa.

(25) Ibid. "Survey of Science and Technology Issues, Present and Future."

(26) Student Achievement in California Schools, 1979-80, Annual Report, State of California.

(27) Ibid. "Survey of Science and Technology Issues, Present and Future."

(28) Data from telephone survey, November, 1981.

(29) Ibid.

(30) Ibid.

(31) Trevor G. Howe and Jack A. Gerlovich. Technical Report 23, Science Education Center, The University of Iowa, 1981.

(32) William Wilken, National Association of State Boards of Education, Private Correspondence, September 3, 1981.

(33) Data from School catalogs.

(34) Ibid. William Wilken, correspondence.

(35) Howard H. Kingsley and Robert W. Fellows, "The Individualized Development Reading Center, Program Descriptions," Fitchburg State College, November 20, 1979.

(36) "North Carolina Science Teacher Profile, Grades 7-12", North Carolina Department of Public Instruction, 1979-80.

(37) Gary Sykes, "Teacher Preparation and Teacher Workforce: Problems and Prospects for the Eighties," National Institute of Education.

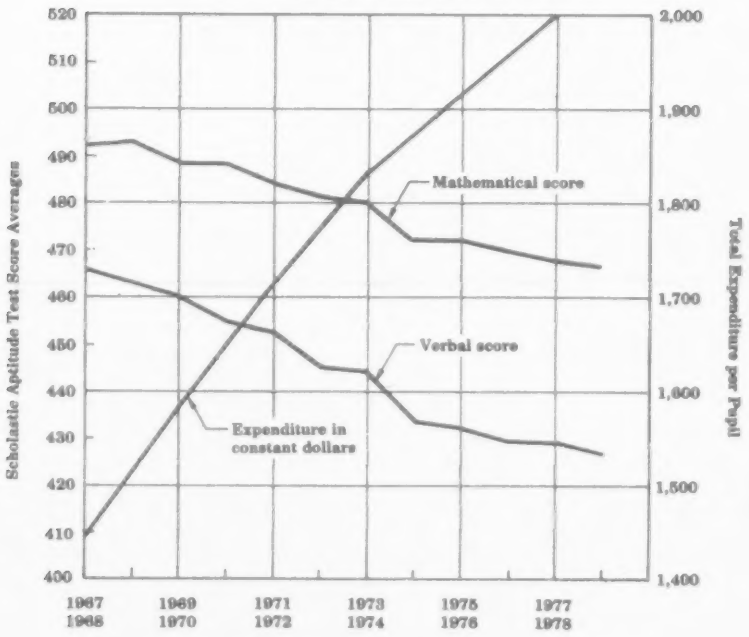
(38) Frank E. Armbruster, "Our Children's Crippled Future," The New York Times Book Company, 1977.

(39) Alex Inkeles, "Proceedings of the National Academy of Education," 1977, pages 185-6.

(40) Diane Ravitch, The Revisionists Revised, Basic Books, New York 1978, page 107.

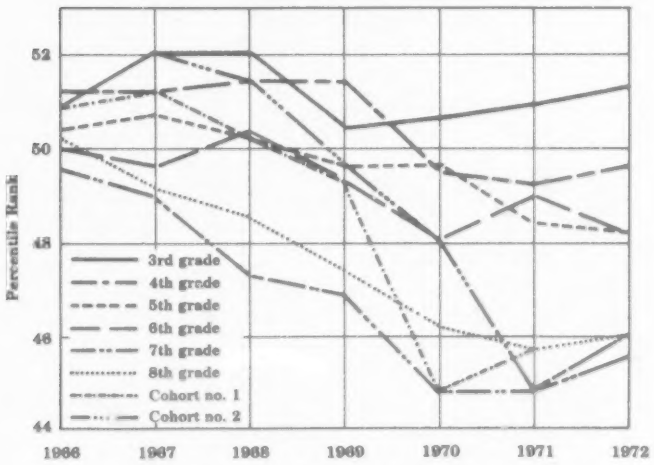
(41) Robert DuPont, San Francisco Sunday Examiner and Chronicle, October 11, 1981.

Figure 1
SCHOLASTIC APTITUDE VERSUS EXPENDITURE
1967-1968 TO 1978-1979



Source: National Center for Education Statistics, "Digest of Education Statistics", 1980.

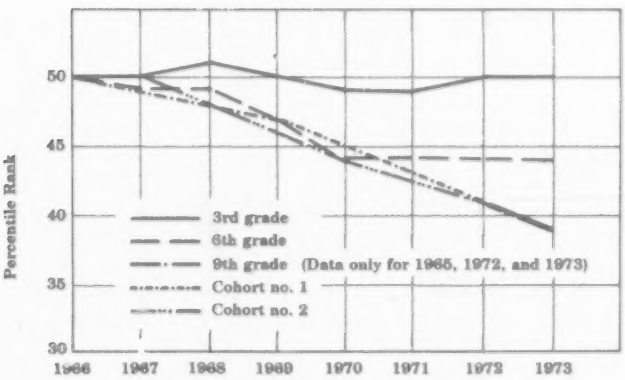
Figure 2
READING SKILL PROGRESS OF PUPIL COHORTS AND TRACES OF READING ACHIEVEMENT SCORES FOR 3RD THROUGH 8TH GRADES, IOWA, 1966-1972
1965 "Base-Year" Percentile Ranks*



Source: Iowa Basic Skills Testing Program. As reported by Frank E. Armbruster in "Our Children's Crippled Future. How American Education Has Failed."

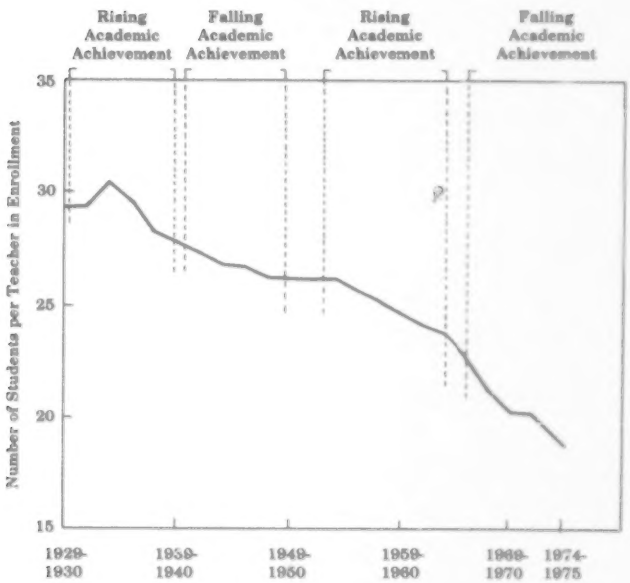
**The fiftieth percentile point for each grade in 1965 is the starting point.*

Figure 3
READING SKILL PROGRESS OF PUPIL COHORTS AND TRACES OF READING ACHIEVEMENT TEST SCORES FOR PUBLIC AND PRIVATE SCHOOLS, 3RD, 6TH, AND 9TH GRADES, NEW YORK STATE, 1966-1973
(Percentile Rank of Median Raw Scores, Pupil Evaluation Program, Base Year 1965)



Source: New York State Pupil Evaluation Program. As reported by Frank E. Armbruster in "Our Children's Crippled Future. How American Education Has Failed."

Figure 4
CLASSROOM SIZE VERSUS SAT SCORES



Source: Frank E. Armbruster with Paul Bracken, "Our Children's Crippled Future: How American Education Has Failed."

Table 1
COMBINED AEA AND MHTC DATA—UNITED STATES

Total, All Categories

Current	1981	1983	Projection Totals	Annual Compounded Growth Rate
286,663	63,025	100,861	163,886	16.2%

Number of Employees*

Technical Professional Categories†	Current	Projected		Projection Totals	Annual Compounded Growth Rate, percent
	1980	1981	1983		
Number of facilities reporting	(671)	(615)	(637)		
Engineers					
Electronics/electrical	45,662	10,436	13,748	24,184	15.2
Mechanical	13,617	2,582	3,607	6,189	13.3
Manufacturing/industrial	7,503	1,519	2,249	3,768	14.5
Electronic engineer technologist	3,709	1,074	1,449	2,523	18.9
Computer professionals					
Software engineer	17,103	5,127	8,286	13,413	21.3
Analyst/programmer	8,936	2,354	4,024	6,378	19.7
Other computer professionals	5,996	1,726	2,638	4,364	20.0
Other technical professionals	43,406	5,378	7,900	13,278	9.3
Total technical professionals	145,934	30,196	43,901	74,097	14.7

* Combined AEA-MHTC data is in bold print. All other figures report AEA data only.

† **Technical Professionals:** Those who hold jobs which require a bachelor's, master's, or doctorate degree or experience of such kinds and amounts as to provide a comparable background.

Source: American Electronics Association, "Technical Employment Projections of Professionals and Paraprofessionals", 1981-1983-1985

Table 2
PROJECTED ENGINEERING DEGREES—1976-1987

Year	B.S. in Engineering	B.S. in Technology	M.S. in Engineering	Doctorate in Engineering
1976-77	44,990	8,990	16,250	2,810
1977-78	53,960	8,560	16,230	2,900
1978-79	57,400	9,350	16,380	2,770
1979-80	61,190	9,870	16,290	2,750
1980-81	61,410	10,310	16,410	2,740
1981-82	61,290	10,700	16,400	2,690
1982-83	60,960	11,040	16,430	2,650
1983-84	60,490	11,280	16,440	2,630
1984-85	59,510	11,600	16,410	2,580
1985-86	58,210	11,750	16,350	2,550
1986-87	56,660	11,960	16,280	2,500

Source: NCES (Prepared by Task Force members of AAES, ASME, and ASEE.)

Note: NCES estimates exceed the actual count of awarded degrees made by EMC by 10 percent or more.

Table 3
GROWTH PROJECTIONS BY COMPANY SIZE
UNITED STATES

	Technical Professionals			Technical Paraprofessionals		
Number of Employees	1980	Projected Increase 1981-1985	Annual Compounded Growth Rate, percent	1980	Projected Increase 1981-1985	Annual Compounded Growth Rate, percent
1-50	972	5,709	47.0	1,033	9,095	57.9
51-100	1,779	5,610	32.9	2,305	10,068	39.9
101-200	3,123	6,409	25.0	3,333	8,705	29.3
201-300	1,743	3,090	22.6	3,581	7,199	24.7
301-400	2,413	2,904	17.5	2,486	5,075	24.9
401-500	2,542	2,551	14.9	3,551	4,862	18.8
501-1,000	8,913	9,270	15.3	11,269	9,686	13.2
1,001-2,000	13,870	13,580	14.9	22,431	25,002	16.2
2,001-5,000	27,964	14,917	8.9	21,277	12,489	9.7
5,001-10,000	30,267	15,374	6.8	16,631	7,678	7.9
Over 10,000	24,194	16,884	11.0	22,806	13,184	9.6

Source: American Electronics Association, "Technical Employment Projections of Professionals and Paraprofessionals", 1981-1983-1985.

Table 4
PERCENTAGE OF ENGINEERING GRADUATES TO TOTAL BACHELOR'S DEGREES
(Latest Year Available From UNESCO)

Country	Total Graduates*	Engineering Degrees*	Engineering Degrees, percent*	Population 1978†	Number of Engineering Degrees per 100,000 People
Bulgaria	14,661	5,880	40.4	8,840,000	66.51
Czechoslovakia	22,306	7,212	32.3	15,150,000	47.60
East Germany	43,205	17,356	40.1	16,570,000	104.74
Hungary	11,766	5,535	47.0	10,700,000	51.72
Poland	26,578	10,939	41.1	35,050,000	31.20
Romania	30,839	12,260	39.7	21,630,000	56.66
West Germany	60,436	22,400	37.1	61,250,000	36.56
Japan	345,122	65,423	20.7	114,850,000	56.96
United States	949,000	54,500	5.8	215,525,000	24.9

*Source: Dallas Morning News, Paul Kolata.
†Source: Information Please Almanac, 1979.

Table 5
ENGINEERING DEGREES, 1950-1980—UNITED STATES

Year Ending	B.S. Degrees		M.S. Degrees		Doctoral Degrees	
	Foreign Nationals	Total	Foreign Nationals	Total	Foreign Nationals	Total
1950	NA	48,160	NA	4,965	NA	492
1951	NA	37,887	NA	5,134	NA	586
1952	NA	27,155	NA	4,132	NA	586
1953	NA	24,265	NA	3,636	NA	592
1954	NA	22,236	NA	4,078	NA	590
1955	NA	22,589	NA	4,379	NA	599
1956	NA	26,306	NA	4,589	NA	610
1957	NA	31,221	NA	5,093	NA	596
1958	NA	35,332	NA	5,669	NA	647
1959	NA	38,134	NA	6,615	NA	714
1960	NA	37,808	NA	6,989	NA	786
1961	NA	35,860	NA	7,977	NA	943
1962	NA	34,735	NA	8,909	NA	1,207
1963	NA	33,458	NA	9,480	NA	1,378
1964	NA	35,226	NA	10,837	NA	1,993
1965	NA	36,691	NA	12,346	NA	2,124
1966	NA	35,815	NA	13,677	NA	2,303
1967	NA	36,188	NA	13,887	NA	2,614
1968	NA	38,002	NA	15,182	NA	2,933
1969	NA	39,973	NA	14,980	NA	3,387
1970	NA	42,986	NA	15,548	NA	3,620
1971	1,565	43,167	2,930	16,365	741	3,640
1972	1,944	44,190	2,973	17,356	773	3,774
1973	2,136	43,429	2,551	17,152	708	3,587
1974	2,436	41,407	3,099	15,885	1,014	3,362
1975	2,488	38,210	3,250	15,773	891	3,136
1976	2,799	37,970	3,628	16,806	1,060	2,977
1977	2,996	40,095	3,825	16,551	995	2,813
1978	3,084	46,091	3,720	16,182	874	2,573
1979	3,788	52,598	4,068	16,036	929	2,815
1980	4,866	58,742	4,512	17,343	982	2,751

Data for 1950-52 taken from Facilities and Opportunities for Graduate Study in Engineering, Amer. Soc. for Engrg. Educ., Washington, D.C., March 1955. Data for 1953-78 supplied by Engineering Manpower Commission, New York, N.Y. Data for 1969-79 taken from Engineering Manpower Bulletin No. 50, Nov. 1979, Engineers Joint Council, New York, N.Y. 1980 data taken from Engineering Manpower Commission data. (Prepared by Task Force members of AAES, ASME, and ASEE.)

Table 8
COMBINED AEA AND MHTC DATA—UNITED STATES

Number of Employees*

Paraprofessional/Technician Categories†	Current	Projected		Projection Totals	Annual Compounded Growth Rate, percent
	1980	1981	1983		
Number of facilities reporting	**(871)**	**(591)**	**(806)**		
Technicians and aides					
Applications programmer	**2,227**	**759**	**1,203**	**1,962**	**23.4**
Engineering aide	3,339	747	1,261	2,008	17.0
Master/super technician	4,061	942	1,429	2,371	16.6
Electronic technician	**13,912**	**4,264**	**7,028**	**11,982**	**17.6**
Jr. technician/tester	4,874	1,367	2,455	3,822	21.3
Field service technician	**10,453**	**2,823**	**4,531**	**7,154**	**19.0**
Micro-electronic technician	510	139	245	384	20.6
Laser technician	176	100	127	227	31.8
Assembler/operator	**65,886**	**18,744**	**26,758**	**44,502**	**18.8**
Drafters					
Drafter	**3,787**	**1,204**	**1,714**	**2,918**	**21.0**
Design drafter	**2,723**	**805**	**1,125**	**1,930**	**19.6**
Machinists					
Machinist	5,833	855	1,296	2,151	11.0
Other paraprofessional/ technicians	**19,948**	**3,290**	**5,186**	**8,478**	**12.5**
Total paraprofessional technicians	**142,729**	**32,839**	**50,960**	**89,799**	**17.7**

*Combined AEA-MHTC data is in bold print. All other figures report AEA data only.

†**Paraprofessional/technicians:** Those who hold jobs which require a combination of knowledge of basic theory and manual skills obtained through 2 years of community college, vocational school, or equivalent on-the-job training.

Source: American Electronics Association, "Technical Employment Projections of Professionals and Paraprofessionals, 1981-1983-1985."

Table 7
SUMMARY OF ENROLLMENT IN EDUCATIONAL INSTITUTIONS*, WITH PROJECTIONS, BY LEVEL OF INSTITUTION
(Fall 1970 to Fall 1988)

Enrollment (thousands)

Fall of Year	Total Enrollment	Elementary Schools (grades K-8)	High Schools (grades 9-12)	Institutions of Higher Education
1970	59,899	36,086	14,632	8,581
1971	60,182	36,088	15,116	8,948
1972	60,000	35,569	15,216	9,215
1973	59,982	34,999	15,380	9,603
1974	60,340	34,504	15,832	10,234
1975	61,063	34,174	15,704	11,185
1976	60,807	33,768	15,727	11,012
1977	59,965	32,961	15,720	11,284
1978	58,948	32,061	15,828	11,350

Enrollment Projection (thousands)

Fall of Year	Total Enrollment	Elementary Schools (grades K-8)	High Schools (grades 9-12)	Institutions of Higher Education
1979	58,129	31,376	15,345	11,508
1980	57,382	30,974	14,797	11,611
1981	56,602	30,614	14,296	11,686
1982	55,695	30,217	13,808	11,670
1983	55,381	30,273	13,495	11,613
1984	55,122	30,208	13,422	11,492
1985	55,111	30,257	13,496	11,358
1986	55,292	30,675	13,402	11,215
1987	55,576	31,369	13,103	11,104
1988	55,938	32,223	12,667	11,048

**Includes public and private institutions.*

Note: Details may not add to totals because of rounding.

Source: U.S. Department of Health, Education and Welfare, National Center for Education Statistics, "Projections of Education Statistics to 1988-89", 1980.

Table 8
MEAN AMOUNTS BY WHICH READING GRADES OF 1937 PUPILS AT A PARTICULAR GRADE LEVEL EXCEEDED READING GRADES OF 1957 PUPILS
(Expressed in Tenths of Reading Grade)

Grade	Mean	Grade	Mean
3.5	0.07	6.0	0.21
4.0	0.09	6.5	0.24
4.5	0.11	6.9	0.25
5.0	0.14	7.5	0.28
5.5	0.18	8.5	0.34

Source: Arthur I. Gates, "Reading Attainment in Elementary Schools: 1957 and 1937," Teachers College Press, 1961, p. 20. As reported by Frank E. Armbruster in "Our Children's Crippled Future: How American Education Has Failed."

Table 9
DISTRIBUTIONS OF IOWA HIGH SCHOOL PUPIL SCORES

Subject Matter Test	1934 Group Mean	1954 Group Mean	Differences
1934 9th Year Algebra	14.3	10.9	3.4
1934 General Science	43.9	42.9	1.0
1934 English Correctness (9th Grade)	61.9	45.6	16.3
1934 United States History	42.4	37.3	5.1
1933 United States History	47.0	39.3	7.7

Source: Joseph R. Sligo, "Comparison of Achievement in Selected High School Subjects in 1934 and 1954," Ph.D. dissertation, State University of Iowa, p. 152. As reported by Frank E. Armbruster in "Our Children's Crippled Future: How American Education Has Failed."

Mrs. HECKLER. Thank you very much.

Dr. Seamans, it is a pleasure to see you again. We had extensive contact when you were Secretary of the Air Force.

I understand you have just stepped down as dean of the school of engineering, but you are now the Henry R. Luce professor of engineering and environmental policy.

We are delighted to have your input at our hearing today.

Mr. SEAMANS. Thank you very much, Mrs. Heckler. I am happy to have an opportunity to appear before your Subcommittee on Science, Research and Technology. Though I recognize the many strong and important ties between the sciences and engineering, and the difficulty of drawing a fine line between these two important arms of human endeavor, my remarks will be primarily directed toward the latter with emphasis on engineering education at graduate and undergraduate level.

I would like to make it clear, however, that I do not minimize the alarming issues of primary and secondary education so well and thoughtfully covered by Mr. Henderson.

The demand for engineers in the United States has recently reached record highs as reflected in the number of job openings as well as the salaries offered.

The causes include the high level of private sector spending on energy technologies, the need for improved environmental controls, higher defense spending, continued growth of computer technology and its applications, and emerging new technologies such as genetic engineering, and the reaction of industrial organizations to challenge foreign competition.

Students are well aware of present opportunities in a profession, and engineering enrollments reflect their perception.

The annual number [1] of students graduating with B.S. degrees in engineering was over 50,000 in 1949 and 1950. This number dropped dramatically to a low of 25,000 annually in the midfifties. Since then the overall trend has been upward with a marked drop in the early seventies prior to the recent surge from 32,000 to a record 60,000 last year.

Hence it appears that supply and demand are approaching balance at the undergraduate level although this has not yet been achieved.

However, the industrial demand for engineers is so great that salaries have escalated well above university opportunities for graduate studies and hence the number of students receiving doctors' degrees has been shrinking while the masters' level is remaining nearly constant.

The number of doctorates awarded in engineering has dropped by about 25 percent from the peak level in the early seventies while at the same time the number of foreign students receiving doctorates from our universities has increased to between 35 and 40 percent of the total.

---

[1] These and other statistics are contained in an article by Hansen and Seamans entitled "Engineering Education for the Future" appearing in the Technology Review of February/March 1981.

The number of U.S. students receiving doctorates in engineering reached nearly 3,000 in the early seventies, and last year was distressingly low, less than 2,000.

The total graduated last year, including the foreign students, was about 2,800.

As a result of this shortfall, it is becoming increasingly difficult to fill tenure track faculty vacancies.

A recent poll of 23 departments of chemical engineering showed 172 vacancies and the total deficit for all departments of engineering in this ccuntry is estimated to be well over 2,000.

During the last 3 years, when I was dean of the engineering school here at MIT, 70 assistant professors were hired, of whom 30 were foreign nationals.

In many cases here at MIT positions were open for well over 1 year. As a matter of fact, we had one position in computer science that took 26 months to fill.

The first offer we made for this position was lower than industry by a factor of over 3 to 1. Of course, there are other than educational requirements for Ph. D. engineers. In 1977 nearly 16,000 were employed by academic institutions, whereas there were 23,000 in industry and 4,000 in the Government for a total of about 46,000, with self-employed and part-time employees making up the balance.

There is general agreement that the graduation rates of Ph. D. engineers have been exceedingly low during the latter part of the seventies and this trend is going to continue into the eighties.

It has not been possible to satisfy the needs for growth and at the same time to accommodate attrition in either our universities, our industry, or in the Government.

Fred Landis, in a paper [1] presented at the annual meeting of the Society of Engineering, estimated that the level of Ph. D.'s graduating must increase by over 500 annually for an average of 3,500 per year during the eighties.

This estimate depends, however, on many factors including the present shortfall, the net migration of foreign professionals to the United States, economic growth, and national security requirements.

Many believe the estimate of 500 is low, but all agree the increase will be difficult to achieve and will necessitate strong measures.

In order to increase the level of graduate education, it must be recognized that research activity is an essential ingredient.

In fields that are changing as rapidly as microprocessing, materials processing, robotics, and bioengineering, the engineering curriculum is far from static. It must be continually revised based on concepts, theories, and data in which the faculty have current, intimate knowledge. Timely transfer to the classroom is achieved only when significant portions of the fundamental research are conducted on campus by graduate students and faculty.

---

[1] "The Demand for Doctorate and Master's Degree Holders in Engineering through 1987," Fred Landis, dean, college of engineering and applied science, University of Wisconsin-Milwaukee, presented at the annual meeting, Society for Engineering Education, Los Angeles, June 1981.

As a consequence, the agenda for support of graduate education in engineering must include support not only for engineering students, but also for expanded research.

To be more specific, I believe there should be increased Government and industry support for expanded research activity on campus; for graduate programs in engineering with awards of 300 to 400 fellowships annually, each with a yearly stipend of $15,000 plus tuition; and for new laboratory equipment and facilities modernization.

I haven't a complete cost breakdown, but the fellowship program would require $28 to $30 million annually for 400 students each financed for 3 years. Facilities support plus seed money for research might require $50 million for a total of $80 million including fellowships to be financed by Government and industry. This amount appears to be a low price to pay for the essential underpinning of our national technical effort.

University support for engineering research and education is presently provided by a variety of Federal departments and agencies. It is imperative that a plan be implemented that integrates all of these activities so that the efforts are focused on the growing needs for trained engineering manpower in this country.

We are rapidly losing our pre-eminence in many technical fields and we must make bold decisions if we are to reverse this trend.

Thank you, that concludes my oral statement.

[The prepared statement of Dr. Seamans follows:]

Mr. Chairman:

I am happy to have an opportunity to appear before your Subcommittee on Science, Research, and Technology. Although I recognize the many strong and important ties between the sciences and engineering, and the difficulty of drawing a fine line between these two important arms of human endeavor, my remarks will be primarily directed toward the latter with emphasis on engineering education.

The demand for engineers in the United States has recently reached record highs, as reflected in the number of job openings as well as the salaries offered. The causes include the high level of federal and private-sector spending on energy technologies, the need for improved environmental controls, continued high defense spending, continued growth of computer technology and its applications, emerging new technologies such as genetic engineering, and the reaction of industrial organizations to the challenge of foreign competition.

Students are well aware of present opportunities in a profession, and engineering enrollments reflect their perception. The annual number of students graduating with B.S. degrees in engineering was over 50,000 in 1949 and 1950. This number dropped dramatically to a low of 25,000 annually in the mid-fifties. Since then the overall trend has been upward, but with a marked drop in the early 70's prior to the recent surge from 32,000 to a record 60,000 last year. Hence it appears supply and demand are approaching balance at the undergraduate level.

However, the industrial demand for engineers is so great that salaries have escalated well above university opportunities for graduate studies, and hence the number of students receiving doctor's degrees has been shrinking while the master's level is remaining nearly constant. The number of doctorates in engineering has dropped by about 25% from the peak level in the early 1970's, while at the same time the number of foreign students receiving doctorates from our universities has increased to between 35 and 40% of the total. The number of U.S. students receiving doctorates in engineering reached nearly 3,000 in the early 70's and last year was distressingly low, about 2,000.

As a result of this shortfall, it has become increasingly difficult to fill tenure-track faculty vacancies. A recent poll of 83 departments of chemical engineering showed 172 vacancies, and the total number of all departments of engineering in this country is estimated to be over 2,000. During the time I was dean of the engineering school at M.I.T., 70 assistant professors were hired, of whom 30 were foreign with permanent visas, and in many cases positions were open for as much as a year.

Of course, there are other important requirements for Ph.D. engineers. In 1977, 15,750 Ph.D.'s were employed by academic institutions, 22,650 by industry, and 4,000 by government for a total of 45,800 if self-employed and part-time employees are also included. There is general agreement

that the graduation rates of Ph.D.'s has been exceedingly low since 1977. It has not been possible to satisfy the needs for growth and, at the same time, to accommodate attrition in either our universities, industry, or in government. Fred Landis[1], in a paper presented at the annual meeting of the Society of Engineering, estimates that the level of Ph.D.'s graduating must increase by over 500 annually for an average of 3,500 per year during the 80's. This estimate depends on many factors, including the present shortfall, the net migration of foreign professionals to the U.S., economic growth, and national security requirements. Many believe the estimate is low, but all agree the increase will be difficult to achieve and will necessitate strong measures.

In order to increase the level of graduate education, it must be recognized that research activity is an essential ingredient. In fields that are changing as rapidly as micro-processing, materials processing, robotics, and bioengineering, the engineering curriculum is not static, but must continually be revised. As a consequence, the federal agenda for support of graduate education in engineering must include support for

- block funding of university research with 3 to 5% annual real growth throughout the decade.
- a new graduate program in engineering which will award 200 to 300 fellowships annually at a yearly stipend of $15,000 plus tuition.
- new laboratory equipment and facilities modernization.

University support for engineering research and education is presently provided by a variety of federal departments and agencies. It is imperative that a plan be implemented that integrates all these activities so that the efforts are focused on the growing needs for trained engineering manpower in this country. We are rapidly losing our preeminence in many technical fields, and we must make bold decisions if we are to reverse this trend.

(1) The Demand for Doctorate and Master's Degree Holders in Engineering Through 1987, Fred Landis, Dean, College of Engineering and Applied Science, University of Wisconsin-Milwaukee, presented at the Annual Meeting, Society for Engineering Education, Los Angeles, June 1981

Mrs. HECKLER. Thank you, Dr. Seamans. Mr. Ryder.

Mr. RYDER. Mrs. Heckler, members of the committee.

I am delighted to join this distinguished panel to give one view of the problem of engineering manpower as I see it.

We have submitted to the committee a full and comprehensive statement. I will speak very briefly to highlight simply the essence of that report.

Northeastern University would certainly affirm the shortages which have been described so dramatically today.

We face an absolute saturation of our facilities, extension beyond capacity of present staff. Our engineering enrollments have expanded something like 50 percent in the past 3 years. They are at the absolute upper limit of capability. I think throughout the Commonwealth as far as I can judge, this is the situation: There is no present excess capacity, so, in effect, something very drastically must be done to help the colleges expand present facilities and staff or, in any event, to try in every way possible to look for alternative sources for such critically needed manpower.

Northeastern University in some respects is a unique institution because it does very firmly commit itself to professional education and because its student body is pretty largely made up of individuals who have one foot in the work world and one on the campus.

This applies to the undergraduates of traditional age who attend under the cooperative plan of education and spend half of their time in class, the remainder at paid employment in industry.

The 21,000 students in this category represent a very important segment of our population. They have a keen understanding from their work experience of what the problems of industry are and certainly are keenly aware of the problems of the present engineering profession.

The other segment of our population, some 35,000 adults, study on a part-time basis.

They too serve as a kind of bridge between the university academic community and industry, working during the day in industry and then bringing their problems and their concerns to programs of training and upgrading in the evening. They continually keep the university aware of the general environment.

In addition to the industry-based students, we also employ a fairly large number of professional experts from industry as part-time faculty in this large adult program.

So in essence we are very keenly and very consciously aware of the needs of the present engineering industry.

Our concern has been expressed in many ways, and I thought today that the best thing I could do would be simply to highlight two messages that I would like to deliver to the committee.

First, that the time is right and long overdue for Government in every conceivable way to encourage a close cooperation and partnership between the engineering and technological universities and industry; to try to encourage and create a better partnership than has existed in the past.

Second, particularly in light of the saturation of traditional facilities for training engineering students, to encourage creative use of new devices for retraining of people already educated in varying

fields, and who may be, in effect, quickly brought into the mainstream to assist in solving the engineering crisis.

A few comments about the first aspect. I believe that in Massachusetts we have established a model in the Bay State Skills Corp. which may be a useful model for the rest of the country and which might, in fact, be encouraged by Congress to be replicated in other States.

It all began, really, about 2 years ago. I sponsored a meeting in my home on a Washington's Birthday afternoon because I was concerned about the failure of Government, business, and education to work together in their planning to deal with this crisis of manpower.

George Kariotis, the secretary of manpower and economic development, a representative of the high tech industry and a representative of Worcester Polytechnic Institute, talked with me for 2 or 3 hours about what we could do to bring together a partnership of these elements which needed one another so desperately.

The byproduct was the establishment of a Bay State Skills Commission, recently renamed the Bay State Skills Corp., which, in effect, attempted to encourage educational institutions to be creative in developing new training programs and to bring together in a dual partnership government at the State level and business, with funding equally being provided by both the State and the private sector.

Perhaps one of the best ways of explaining how this works is by pointing out a program which began at Northeastern this fall.

We launched this past fall a program called women in engineering. It was specifically developed in response to the Bay State Skills Corp. request. We received a grant of some $60,000 from the Government, matched by a comparable amount from industry, to establish a new program that would be especially geared to bringing women into engineering.

It was designed for women who had graduated, not in the field of engineering at all, but from programs where there was a strong science and mathematics component; where, in effect, they showed an interest in science and an aptitude for possible training in engineering.

The program is offered through our graduate school of engineering, leads to a master's degree in either computer science or electrical engineering.

The group of women who have been recruited to the program come from diverse backgrounds, but they have all decided at this point in their career to look to engineering as a potential profession.

The group who came to the campus this past fall I think is a fascinating one: a 55-year-old grandmother preparing to re-enter the job market, a schoolteacher in her twenties whose job was cut, a Wellesley graduate of 1977 who made it in black studies and wants to now redirect to a new career; a recently graduated student, and a mother-to-be who wants to upgrade her skills and move into the field of engineering. There are part-time students in the mix and their are also full-time students.

Those who are full-time in the first year we would expect to encourage to take cooperative education and work experience as part

of their total program so that at the time they receive their masters' degrees they will, in effect, have a full range of experience.

These women in some respects are important because they represent both the culmination of this idea of a partnership planning jointly between industry and the State, but, because they also represent one of the best answers to the immediate shortage of engineers from regular channels.

I have with me today Prof. Barbara Baum from the college of engineering simply to demonstrate there are women engineers who do, in fact, like the job and can serve as real models.

The women in engineering program includes orientation to the workplace. There are faculty who have been loaned from cooperating companies to assist in particularly critical areas of shortage.

It represents, I think, an extremely good model of partnership between State government, education, and industry to meet a critical need. I mention the women in engineering program as symbolizing this aspect of necessary cooperation.

Another point is that we simply must in this period address the possibility of bringing into the mainstream in engineering and science women, minorities, nontraditional students who may, in a much shorter time than the traditional 4 years of college study, be brought productively into the workplace, either in paraprofessional or professional roles.

The women in science program which we also launched this fall at Northeastern University represents a very important illustration of the way that the Federal Government can assist in this training or perhaps retraining of traditional students.

The women in science program, I am happy to say, was supported by $100,000 grant from the National Science Foundation. I mention it rather pointedly to say that this kind of program is simply desperately needed, and I hope funding for such educational ventures of the National Science Foundation will be ongoing and expanding.

The women in science program, like the women in engineering program, takes people who have already had college education; but in this instance women who were trained in the sciences but have not been using the science training or have been out of the labor market for a number of years, and thus need to have professional upgrading and, in fact, be brought up to the point of readiness for employment in the current technological industry of the area.

Similarly, this program which has brought in a variety of people of different backgrounds and a wide range of ages, represents a model for retraining of our present population, which is extremely important. We have launched programs of a similar sort without outside sponsorship in the field of technical writing. We have launched a new master's degree program in English with a technical writing component, an internship program for college educated people which will bring them into the technical writing field with a paid internship in industry as part of their total experience.

For what it is worth, this program currently enrolls students that include many women and also two college professors with Ph. D. degrees who have decided that going into technical writing in industry is a more stable way of paying for family expenses than

continuing in their previous teaching professions, which, incidentally, is true in my own special field, history.

A high school teacher who taught Latin for 7 years is included. There are so many people from different backgrounds. The programs really demonstrate that you can retrain people for employment in high technology companies even though they may have only humanities and social science degrees, not the programs of physics and mathematics that you would normally expect.

The possibility of retraining adults who have varying degrees of prior education, bringing them up to skills level that will allow them to mesh into the needs of high technology companies, it seems to me, presents a very interesting challenge for all universities and certainly deserves encouragement from the Federal Government.

We have been, at the other end of the spectrum from the Ph. D.'s that are being retrained, trying to tie in in recent months with the CETA training institutions in the local area. We have arranged with five of the CETA training centers to upgrade their components of mathematics instruction and technical instruction to mesh more closely with our own programs and have provided advanced standing credit for students in those training programs so they would be encouraged to move over into associate degree technician training courses at the university upon completion of the program.

Whatever the limitations of the public service component of CETA, we have some extremely high quality training programs that have been spawned by that Federal legislation. I would certainly hope that there is some attempt made to preserve some of those training centers that have such an excellent opportunity to interface with the hard to employ and to challenge them and bring them into technological employment at a later time.

The hour is short. I have presented other thoughts in my formal paper to the committee. I believe this is a time when there is an opportunity for cooperation, for getting together and thinking both in industrial and educational terms of ways we might be able to combine our efforts.

We have now underway a very, I think, fascinating example of this kind of cooperation. Last spring I sponsored a meeting with the major engineering college presidents of the area, MIT, University of Massachusetts, WPI, University of Lowell, Northeastern.

We began a discussion of ways in which these engineering colleges could cooperate in the future.

During the course of several meetings, we began to develop a plan for common action to try to deal with the high technology employment needs, and during the summer the deans of those institutions, with the addition of deans from SMU, Tufts, and Boston University, have established a regular series of meetings to communicate, to begin to plan jointly, and to explore ways in which there may be collaboration not only in teaching, but also in research.

We believe that as never before the educational community in Massachusetts is prepared to join with industry in a partnership for the general welfare of our society and we urge the support of Government in creatively encouraging a further development of that partnership.

[The prepared statement of Mr. Ryder follows:]

Testimony of

Kenneth G. Ryder
President of Northeastern University

Before the

Subcommittee on Science, Research & Technology
of the U.S. House of Representatives' Committee
on Science and Technology

Cambridge, Massachusetts
November 24, 1981

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I appreciate the opportunity to testify before the Committee this morning on ways in which government, industry and higher education can be brought together in a unified and concerted effort to provide a professionally educated work force in the areas of science and technology for the Commonwealth of Massachusetts and for the nation.

Northeastern University is especially sensitive to the manpower needs of industry since we concentrate on educating people for professional fields and most of our students spend their lives in regular alteration between industrial or professional employment and classroom study.

For students of traditional college age we offer undergraduate and graduate programs on the cooperative plan, a philosophy of education which in a carefully structured way integrates academic study with occupation-related work experience. The approximately 21,000 students enrolled in our co-op plan not only earn most of their college expenses but also gain keen insights into the world of work and bring back to the faculty and administrators of the University an

89-542 O—82——8

understanding of the needs and problems facing employers in industry.

The Cooperative plan encourages close coordination and communication between industry and the university, because employers view co-op universities as excellent agencies for recruiting trained professional employees. Co-op employers experience substantial savings in recruitment and training costs and are able to evaluate potential employees in actual work situations and identify the very best before they are available for post-graduation placement. Employers especially appreciate the chance to get an early look at monority and women students of ability, since in fields like engineering, such professional applicants are in short supply.

In another important way Northeastern is also tied closely to local industry, commercial and professional employers; namely, through a remarkedly diverse and extensive range of programs designed for working adults who wish to study on a part-time basis. Last year we enrolled over 35,000 students in this category, largely persons working full-time in local or regional industry and taking academic courses one or two nights a week. In this aspect of endeavor the University can be viewed as in close partnership with industry, since our programs provide established employees with a mechanism for developing their professional competencies and up-grading their skills so that they can be assigned increased responsibilities by the employers. Employers frequently encourage such

educational efforts of their employees by providing partial or full coverage of tuition costs. In this large scale educational effort the University employs many experts from industry and business as part-time adjunct faculty members. The infusion of such part-time teachers of engineering, accounting, management, computer science, health science, etc., makes the University keenly aware of the attitudes, needs and challenges which such professionals are addressing on a day-to-day basis.

Because of the close working relationship which has been established between Northeastern University and local employers, a large number of our graduates move routinely into professional positions with regional employers. A recent survey of high technology firms in Massachusetts sited Northeastern as the largest supplier of engineering graduates for the one hundred ten companies on the Massachusetts High Tech Council. Almost half of the 1,000 persons hired from eight Massachusetts' universities by engineering companies over the past two years were Northeastern graduates.

It should not be surprising, therefore, that Northeastern as a major University with important ties to industry and business, has in recent years become increasingly concerned at the lack of coordination in planning educational programs geared to the predictable needs of our regional and national economy. In New England, with the rapid growth of high technology, serious shortages of professional and technical manpower have developed, threatening the future growth potential of

our economy. At the same time thousands of unemployed continue to be supported by federal or state funding and many college graduates find it difficult to find employment in the fields for which they have trained.

Seriously concerned, in February of 1980, I arranged a meeting at my home with the Secretary of Economic Development and Manpower Affairs, a leader of the high technology industry and a representative of Worcester Polytechnic Institute to explore ways of encouraging cooperation between government, industry and the universities. Many useful ideas were generated in this informal brainstorming session, with the most promising being the establishment of a state incentive system which would seek to train people in new ways to meet the critical need for persons in technical fields. In the spring of 1980, after further reviews and input from other educational and industrial leaders, Secretary Kariotis, with the warm endorsement of Governor Edward J. King, submitted to the legislature his concept of a Bay State Skills Commission. With discretionary funding from Governor King the program was launched in 1980 and embodied in legislation this year as the Bay State Skills Corporation. The concept is simple. State government will award modest start-up grants to educational institutions to educate persons in areas of acute labor shortage, provided such programs have assurance of financial support and participation by industry.

Let me illustrate the value of the Bay State Skills

Corporation model by describing the program launched this year at Northeastern University called Women in Engineering. Northeastern University is eager to encourage more women to enter the field of engineering and at the same time is interested in developing retraining models which will allow adults with substantial previous education to redirect their energies to career fields which are much in demand by industry. Accordingly, a program was devised in our Graduate School of Engineering to serve the special needs of women who did not have undergraduate degrees in Engineering but might now wish to enter engineering positions in industry. As conceived, the program would be open to any women with strong backgrounds in mathematics and science. Special transitional courses would be offered which would include in condensed form important engineering principles and concepts and thus allow the students to be prepared to pursue a masters' degree in either Computer Science or Electrical Engineering.

Northeastern submitted a proposal to the Bay State Skills Commission and received a $60,000 start-up grant which would cover planning and curriculum development costs, as well as initial administrative expenses related to promotion of the program. This grant was given because the University had developed in cooperation with industry a detailed plan for cooperation. Industrial companies supporting this program agreed to provide paid employment for students, tuition expenses for part-time students in the program and two companies

Data General Corporation and Digital Equipment Corporation agreed to loan four professional employees as part-time teachers, paid for by the companies but assigned to the University as expert lecturers. Thus, in a unique way, partnership of government, education and industry has allowed the initiation of a valuable and innovative graduate program, which after the start-up phase will be jointly financed by the University and supportive engineering corporations. The academic work in this Women in Engineering Program is as rigorous as that offered in ordinary graduate engineering programs, but some of the courses are specifically designed to ease the transition into what are in some cases entirely new areas of study. A course in career development which includes seminars on job opportunites in the high technology industry, field trips to high technology firms and regular lectures by members of the Society of Women Engineers will help to prepare the students for entry into their newly chosen career fields.

The Women in Engineering Program began this fall at Northeastern with eighteen students; seven enrolled on a full-time academic basis and eleven enrolled as part-time students. The participants include a fifty-five year old grandmother who is preparing herself to re-enter the job market; a school teacher in her twenties whose job was a casualty of Propostion 2½; a Wellesley College graduate of 1972 who had majored in Black Studies but is now eager to shift careers, and a recently graduated mother-to-be who

wants to upgrade her skills and marketability. Most of the part-time students are currently employed in industry and tuitions are being paid by the employers. Five of the seven full-time students have received full scholarships from the University. After their first year, the full-time students will be placed in appropriate cooperative jobs in high technology companies and paid according to normal company pay scales. Additional students will be recruited into the program later this year and we would expect to have twice as many enrolled by next fall.

I have described the University's Women in Engineering Program in some detail because I believe it may offer a useful model for the federal government. It would seem reasonable that the federal government might encourage other states to replicate the model of the Bay State Skills Corporation in Massachusetts. Perhaps in the form of matching contributions or challenge grants, states throughout the nation might be encouraged to bring together government, industry and education leaders in planning programs which would be designed to meet the specific needs of the local or regional economies.

For many years the National Science Foundation has been doing excellent work in supporting advanced training programs for students in technological fields. This fall at Northeastern we began a program funded in part by a $100,000 grant from the National Science Foundation which we call Women in Science.

Twenty-seven women whom the University has identified and in some cases recruited, who seek to re-enter the labor market are currently enrolled in the program. The curriculum has been designed to strengthen and update the previously acquired skills in mathematics and science of women who have been out of the workforce for some time or who have held positions where their skills languished unused. These women, like those in engineering, will be encouraged to follow the cooperative employment model and seek job placements so that they will have relevant work experience as well as superior skills when they complete their program and are prepared to enter into industrial employment. It is my hope that your committee will give firm support to such ongoing educational programs as those operated under the National Science Foundation.

As in the two instances cited above, Northeastern University intends to expand and develop new full and part-time credit programs to meet the needs of women, minorities and non-traditional adult students and to retrain them wherever possible for employment in technical fields of the greatest employment opportunity. Beyond that, we have begun to seek ways of reaching and bringing into higher education teenagers and adults who have dropped out of the educational process. As the demographic decline of the coming decade begins to make its impact on the labor market, when Massachusetts high schools will graduate about 40 per cent fewer students than in recent years, it is more and more important that both educational

institutions and industry make efforts to reach older individuals who have great potential to serve at various levels in technical employment. To suggest the range of programs that may be developed I would like mention two areas in which the University is currently active. First, we have developed special programs to train people to be employed as technical writers in industry. We have initiated a new masters' degree program in English with a technical writing component. In addition, we have begun a one year internship program for college educated people which combines intensive training in technical writing and computer science with six month paid internships in private industry. This latter program currently enrolls thirteen students, a majority of whom are women, including two former college professors with Ph.D. degrees, a high school teacher who taught Latin for seven years prior to losing his job to Proposition 2½ and another teacher who feels threatened by current cutbacks in educational budgets. These programs demonstrate the possibility of retraining persons in the humanities or social sciences who may wish to find employment in high technology companies.

Second, in conjunction with five CETA job training centers in the area, we have developed a program whereby people who have completed CETA training in high technology fields will be eligible to continue their training with advanced placement in associate degree programs of our Lincoln College. I should add here in passing that our investigation and experience has

demonstrated that many of the job training centers established under the aegis of the Comprehensive Employment and Training Act are sound and successful mechanisms for directing people toward productive jobs. Whatever the liabilities and inadequacies of the public employment provisions of the act, I would hope that the federal government can continue to support and perhaps enlarge support of those training centers which prepare people for work in technological fields.

Earlier in this testimony I mentioned my personal concern at the previous failure of business, government and education to talk together or plan together. There are strong traditions of autonomy among institutions of higher education in this region and throughout our nation and occasionally an understandable spirit of competition or rivalry has discouraged fruitful cooperation. In February of this year I sponsored a meeting of the presidents of the five major engineering universities in the Commonwealth: the University of Massachusetts, University of Lowell, Worcester Polytechnic Institute, Massachusetts Institute of Technology and Northeastern University. Since then we have had additional meetings to explore our common concerns in responding to the human resource needs of the Massachusetts high technology industries. In addition, it was my hope that through such regular meetings we could achieve broad consensus and provide a common voice for engineering education in the state.

My minimum aspiration is that an informal consortium

of institutions of higher education concerned with technological fields would accomplish the following:

1. Initiate educational planning of programs which will respond to the technological developments anticipated over the next decade.
2. Exchange information to prevent duplication of efforts among the engineering universities and identify areas in which collaboration would be desirable.
3. Experiment with new strategies for updating the skills of practicing professional engineers.
4. Work together to gain support of the state government for joint ventures such as combined research facilities or training centers which will serve the vital needs of high technology industries.
5. Initiate reliable and regular studies of work force supply and demand in high technology fields for the coming decade, so that appropriate academic planning can coordinate education at the colleges with manpower demands in industry.

Already this summer the engineering deans of the consortium institutions, along with the engineering deans of Southeastern Massachusetts University, Tufts University and Boston University, have met regularly to explore where joint approaches and common programs might be developed. While it is too early to predict direct and tangible results of this collaboration, I believe it is important that educational administrators at the highest level

in Massachusetts are beginning to work together and that they recognize that industry, education and government must collaborate effectively if we are to make the best use of our human resources.

Any recomendations I might make to this committee and through it to the Congress are, I think, implicit in my testimony. Whatever encouragement in terms of dollars, public awareness or research which Congress can give to the kinds of initiatives I have outlined here today will help to ease our task. Congress has in the recently passed Economic Recovery Act of 1981 given tax incentives for industry to encourage their donation of equipment to colleges and universities to foster research on university campuses. I would recommend that further incentives of this nature be considered. For example, industry might be encouraged to contribute new equipment so vitally necessary in the training of engineering and science students. Many college laboratories are becoming woefully out of date and the quality of instruction would be greatly enhanced if industry could be encouraged to donate state-of-the-art equipment not only for research but also for instruction.

I especially recommend that this committee and the Congress give attention to the national need for encouraging the upgrading and retraining of adults in our population who may find it necessary to study on a part-time basis. Millions of women, minorities and underemployed persons may be encouraged to move

toward fields in science, engineering or technical programs at various levels. Our greatest national treasure is the energy, intelligence and skill of our people. We must see that they are all given an opportunity to develop to the highest potential and guided into careers which meet our national needs. Northeastern University is committed to accomplishing as much as it can in meeting this challenge. We urge that Congress support any measures which will encourage further cooperation between higher education and industry, since a fruitful partnership of these important institutions has the possibility of enhancing greatly the economy of the nation and ensuring relevant and rewarding careers for millions of our citizens.

I thank members of this committee for the privilege of appearing before you and presenting my views.

Mrs. HECKLER. Thank you very much. Obviously we support the same objectives. I want to say while innovation may be the hallmark of small businesses, it is also the hallmark of some large universities.

I would place great emphasis on your innovation and your leadership at Northeastern Unversity.

I have to say you have warmed my heart in the sense of your comments on the women in engineering and science programs. Mr. Henderson and other witnesses also spoke about the potential of women, and I am delighted to have it introduced, I happen to have been the author of an amendment to the National Science Foundation authorization bill which suffered some difficulty, but did pass, to keep the women in science program alive.

I am only sorry that our colleague, Mr. Gregg, is not here, because he was an opponent of the amendment.

So this testimony will be brought to his attention.

With the bipartisan support of Mr. Walgren and others on the committee, we were able to secure passage of the amendment and still had to fight the same fight on the floor of the House. It was about to be removed by committee action. Again we did succeed. Hopefully this essential program will continue despite its infancy.

At this point I would like to ask Professor Baum from Northeastern to join you at the witness table because she will be the only woman witness we have had today. I think that fills an important vacancy.

I would like to add another witness to this panel, another very distinguished panel, Dr. Herbert Holloman, presently the director of the Center for Policy Alternatives, formerly the Assistant Secre-

tary of Commerce for Science and Technology and formerly the president of the University of Oklahoma.

It is a pleasure to have Dr. Hollomon with us. I would like to hear your comments and have you join this panel.

TESTIMONY OF HERBERT HOLLOMON, DIRECTOR, CENTER FOR POLICY ALTERNATIVES, M.I.T.

Mr. HOLLOMON. I concur with most of what has been said today about small new enterprises. However, I would like to bring to your attention two facts based on studies of the startups in the Silicon Valley, Boston, and Sweden which have not been brought out by the previous witnesses.

First, the average age of the new firm entrepreneur is 32. Second, the number of starts and the likelihood of success depends on the level of education of the entrepreneur.

In other words, the more education he has, the more likely he is to succeed and the more companies he is liable to start.

These facts are true, in addition to all of the things that have been brought out by the previous panel.

This would indicate to me that if all the Ph. D.'s, for example, went into education or into established firms, the Nation's capability for starting new firms would be impaired.

I am concerned not really so much about the future success of the gentlemen who are on the panel and their businesses but rather I am concerned that the next time you come here there will be 20 more of them, I think that the key problem is the startup, not how the firm grows after it has begun.

Venture capital in my opinion does not really help very much when the firm is beginning.

When the firm is at its very beginning, which some people call the "zero stage" before there is any business, the money comes from family and friends and not from venture capital. Consequently, the committee should examine ways of encouraging startups. I think that is important.

Turning to the education question, we have for the last decade at my center been concerned with the supply of engineers and other professionals. These studies were initiated by Prof. Richard Freeman of Harvard University about 8 years ago. We have learned much from these studies.

There are certain things that we know about the training of professionals in this country. The first is that people choose the fields they are to enter. The important thing about the choice of a higher educational field is that the individual chooses. I don't think this committee should forget that. That is a very important fact. We don't do what the Soviets do, which is to decide how many people we need in nonferrous metallurgy and then train that number, willy-nilly.

The second important consideration is that the people who take up a given course of college training today do so in response to what they see as today's business opportunities, not last week's, not 5 years ago, not 5 years from now, but today's.

If there is a great demand for engineers today, there will be a huge number of people applying to engineering school. That is just what is happening today.

The third feature, which really derives from the first two, is that the time when today's beginning engineering students will enter the job market is 4 or 5 years from now.

Hence, we cannot do very much to increase the number of engineering graduates next year because the people who graduate next year came into the university 5 years ago.

So I would like to point out that the increase in the number of students enrolling in engineering in any university in America today will increase the supply not immediately but 4 or 5 years from now.

I believe, though I can not prove this, that there will then be a glut of engineers. I believe that the current large increases in engineering enrollment will result 4 or 5 years from now in the graduation of a very large number of engineers, possibly more than the demand. We cannot say this with a high degree of certainty because predicting the future of the demand is just too difficult.

We have tried that. We haven't succeeded very well. We hope to get back to that task and do it better, but the most important point that I wish to make is that the supply of engineers, like the supply of lawyers, or doctors, is cyclical in America. This is a direct result of the fact that our economy is not planned, that we let people choose their own courses, and that they base their choices on inadequate information. They choose on the information available to them in the newspapers, from their brothers, their sisters, their uncles. This information is relevant to the job market at the time they embark on their training and consequently may have little relevance to the job market they will find when they graduate.

In the last 5 years the rate of growth of enrollments in engineering has been stupendous, and it is my belief that as long as this demand which everybody has told you about continues, enrollment increases will continue as well.

Despite this growth in enrollment, there is currently a shortage of engineers. Consequently, our efforts to alleviate this shortage should be focused on the near term. There are at least two courses of action that could help.

First, as you have heard from other speakers, the equipment available to train engineers is inadequate and needs to be updated. Second, and most important, we must deal with today's shortage by increasing today's supply. We must retrain those already in the labor force to do other things.

What we need to do is either (a) find new pools of people who can be brought into this field or (b) take people who are already somewhere near it and give them continuing education.

We know how to do this, if we wish to.

Mr. Ryder has indicated what Northeastern University is doing. There are other people as well who know how to train, retrain, or reinvigorate people who have already left school.

Frankly, there is almost no support in this country for that kind of activity. For example, look at the National Science Foundation. It has already opted out of programs of education in science and engineering.

NSF is a strange organization. The Congress passed, both House and Senate, the Stevenson-Wydler Act to work on industrial technology and the problem of the supply of engineering talent. The National Science Foundation was chosen as one instrument of implementing that act. Do you know how much money they are going to spend next year doing that? As far as I can figure, it is something less than zero. By something less, I mean it will discourage people from doing anything.

The other agency of the Government that was charged by Congress to deal with this act was the Commerce Department. Now, I had hoped beyond hope that the Secretary of Commerce would be here today and I would have hoped that somebody on the committee would have asked him what happened to the instructions of the Congress about the Stevenson-Wydler Act; to date nothing has happened.

Furthermore, the official responsible for this implementation, who was one of my successors as Assistant Secretary of Commerce for Science, Technology—later changed to Assistant Secretary for Productivity, Technology and Innovation—has been eliminated. So one of the responses of the Commerce Department to the Congress is, get rid of the fellow who would implement what you want. The same problem exists at NSF. They still have a mandate and a staff, but they have no budget.

I presume that this is the result of that great distinguished statesman, Mr. Stockman, and not really the responsibility of NSF and the Secretary of Commerce. I don't know. I used to know. I used to be down there amongst a few people and had my ear to the ground.

Mrs. HECKLER. Everything is more mysterious now, by the way.

Mr. HOLLOMON. Apparently so mysterious that nobody knows what the budget figures are. That is remarkable too.

Anyway, let me reiterate that the most important thing about engineering enrollments and supply is that it is cyclical. If we do things today, it is going to have an effect 4 or 5 years from now. Now, that does not say it can't have some effect today, but I would commend you to examine the possibilities of supporting imaginative, new approaches to continuing education in order to bring new people into the engineering work force that are not in it today.

Finally, let me make some comments about the education of foreign nationals. I don't know whether this country really wants to say that we won't educate foreigners in our schools. I doubt whether we want to do that for two reasons: The first is a pragmatic reason. My suspicion is that one of the reasons that the high technology foreign trade has grown is that we have a lot of friends over there in those countries that we educated and trained.

I suspect that graduates of American engineering and science schools who go to live in foreign countries do, in fact, help promote the relationships with industry, and incidentally with universities, in this country.

Mrs. HECKLER. I am sure that is true.

Mr. HOLLOMON. They also help their own countries grow and produce a market for us.

In addition, simply on human value grounds, I think we have a certain responsibility to help other countries develop their own technology, even though it may hurt us in the future.

I think it is time the north/south dialog began to be a dialog and not a confrontation.

Mrs. HECKLER. Dr. Hollomon, you have added some very interesting points to the discussion. I think we should pursue them as we go through the questions with the panel.

Mr. HOLLOMON. Thank you.

Mrs. HECKLER. I want to say that now, Mr. Henderson, you have perhaps a competing viewpoint on this question of supply. Is there an overabundance? Is there going to be an oversupply, or are we faced with the serious problem of an eventual undersupply as Mr. Wellington said earlier?

Mr. HENDERSON. That is a question that covers a lot of different areas.

I don't think there is any question that today we have an undersupply.

I wouldn't disagree with Mr. Hollomon on that. I think part of the solution is in many of the points that were raised by Mr. Ryder.

I would somewhat disagree, however, as we look out, based on my premise that we are not preparing enough qualified students at the secondary level, that the supply is going to increase enough if you take into account the demographics that we are going to get into, the increasing number of people that we need with a declining number of students and lack of preparation at the secondary school level.

Mr. WALGREN. Something concerns me that perhaps fits with both your points.

That is, your premise is the demand will pull the supply, Mr. Hollomon.

Is that not why it is cyclical?

Mr. HOLLOMON. No; supply and demand determine price. If supply exceeds demand, the price drops. Therefore, people do not go to school.

Mr. WALGREN. But what I wanted to ask and raise was that politically we are going through a period now which given human nature, I am not so sure will end, and that is a failure to provide the demand side of that coin on the local level, on the secondary level, in the schools that will be necessary to allow a cyclical response or even a cyclical response let alone an evenly drawn supply; and you have proposition 2½; and in my part of the country, the refusal of people to support local government.

At the same time, at the national level we are pulling back on all three areas raised by the gentleman right down the line, both the secondary level, we are getting out of that completely in the NSF with the philosophy of the present administration; the NSF is getting out of the whole general support of engineering education, and we are getting out of the CETA business on the other end of the table.

Is there some way that somebody could suggest that we fill in this missing willingness to support the system on the initial level so that we can get those secondary students adequately trained?

My instinct is that on the national administration level, we always swing from one side to the other, cutting off our nose to spite our face on each end of the pendulum. I was thinking whether—and I noticed Mr. Henderson was a trustee of a college that is a favorite of mine—or not there might be a national trustee organization that because of their stature would have political influence with any administration; second, would appreciate the needs of industry; and third, would be very sensitive to the quality of persons flowing into the colleges and provide the demand that will create decent math and science educated students?

Well, that is a long question, but perhaps we could get a general reaction.

Mr. HENDERSON. I see the seeds of something that makes sense. It gets at the issue of establishing broad national priorities. To go back for a second, in the early 1960's, when we had a real challenge with Sputnik. We set some very broad national priorities. We had a terrific increase in the number of people who went into the scientific field. That was done because there was a national crisis, or it was depicted as a national crisis, and I believe it was.

Today I think we are starting to hear those kinds of crisis-type noises come about by people on this panel and even by yourself——

Mr. HOLLOMON. But Mr. Henderson, what I am really afraid of is this: if we overrespond, we are going to put people to real harm.

Mr. HENDERSON. Well, you are assuming that the demand is going to outstrip the supply in 1985 or 1986.

Mr. HOLLOMON. No; I am not.

What I am saying is the following: If you encourage people to make choices toward engineering rather than other fields and then when they come out of school 4, 5 years later, the demand is not there. You will have caused substantial social disruption in the form of unemployment, underemployment, and retraining. I am not assuming that this will happen. I'm simply saying that we ought to be concerned about this possibility. Furthermore, let's suppose every university in this country gears up to produce the chemical engineers that it is believed there is a shortage of. I will predict 5 years from now there will be a chemistry faculty substantially in excess of that required, resulting in the need for a very painful contraction process on the part of universities. Thus we must exercise considerable caution before undertaking a wholesale expansion of university chemical engineering departments.

Mr. HENDERSON. Well, it is a scary risk, actually, if you are right. Your competitors overseas are far ahead of you in terms of the production of engineers per capita, which I think you would admit.

Mrs. HECKLER. Dr. Seamans, would you like to get into this discussion?

Mr. SEAMANS. Yes; I think Mr. Henderson brought up a very real issue that we face in this country and a difficult one to address. It may be that the suggestion of the chairman would be helpful and appropriate. When you come down to it, it is really up to each individual, as Herb Hollomon said, to make his or here choice. The tragedy today is that there are potentially highly qualified scientific and technical people who have no opportunity to become engineers and who, regardless of the numbers, could make an important contribution to this country but they are closed out by virtue

of the fact there are deficiencies in the teaching of math, physics, and other scientific subjects in our secondary schools. Students have, at the same time, no feel for what the profession of science and engineering is all about.

I think that this problem is a reflection of poor guidance and counseling in our schools. I think this is an area where a lot can be done at the local level and where quite a bit is being done in this State by industry to provide an opportunity for youngsters to get out and see what is really going on when they are still at the high school level and still have an opportunity to concentrate in the field.

But that will not solve the whole problem. Obviously there have to be competent teachers as well.

Mrs. HECKLER. Barbara Baum, we asked you to join us at the witness table. I think a comment from you on the women in engineering program would be helpful for the record.

Ms. BAUM. The women in engineering program at Northeastern is relatively new. It is extremely important. There are only two problems that I have with it personally. One is that it is not large enough. It does not have enough women. Of course, it is only a pilot program; it is in its first quarter.

The second is that there are no women in the civil engineering department in which I teach. That is a particular interest of mine and I will tell you why.

I teach the first basic courses for graduate students in getting a masters degree in environmental engineering. In these courses, I see that the males in the classes are predominantly engineers. The females in the classes are not. They are biology majors, chemistry majors, or people working in fields in which they are actually doing engineering but they are not advancing in their jobs because they do not have an engineering degree.

Therefore, they come back to school part time at night in order to get this engineering degree.

Programs such as the women in engineering program would be extremely helpful in facilitating these women who have the necessary foundations and skills to be women engineers to actually accomplish this. And in many cases, it simply cannot be done without outside support. Quite frequently you have women who work all day and go home and still have to do the traditional roles of washing the dishes, getting the kids together to go to bed, taking care of the food, doing the shopping. It is even more difficult for these women who work all day and then go to school part time in the evening.

So in essence, I think that this small start is a very important step for women and engineering, because it begins bringing these women with the technical skills into the mainstream of engineering. I would really hope that this would be expanded and encouraged.

Mrs. HECKLER. I will say. It certainly has the support of many of us on the committee.

I might add that Chairman Walgren's support was critical.

I appreciate the time of the witnesses. I think the early educational emphasis that you placed, Mr. Henderson, on the questions of education remain a major concern of mine. One of my greatest

concerns, aside from the question of adequate manpower, is the declining funding levels for science education. I think you are the first witness to offer possible solutions.

I wonder how you would respond to the loss of the faculty for the local high schools. Superintendents in my district have complained to me that at the very time the high technology industry in Massachusetts is stressing the need for a new program of curriculum infusion for science and math, they are also raiding the best science and math teachers. They are leaving the superintendent with the question as to who will be the educators. How would you respond to this question Mr. Henderson?

Mr. HENDERSON. First of all, I do not think this is necessarily a case of raiding. I do think that the opportunities obviously, as Mr. Hollomon said, on the outside are very good because the price is right. However, a number of people I have talked to on this issue, Mrs. Heckler, who have asked me the same question.

My answer to it does not really come down necessarily to the number of teachers that you have but to the priorities that you place on what you teach at the secondary school level. I mean if you are going—I am not talking about choice. This is not a question of choice. It is not the Soviet Union, obviously. It is a question of saying to someone, you have to take 4 years of physical education—I am not saying that is bad—and 1 year of math. That is the substance of the thing.

It is not really how many teachers you have or how many schools you have or how many pupils you have. It is a question of the priority of what you are going to teach. That is where I think the nub of the problem is.

Mr. WALGREN. Thank you.

Mrs. HECKLER. I would agree. Dr. Seamans.

Mr. SEAMANS. I would make one point we have not stressed sufficiently. We have been emphasizing the need to educate scientific and educational people. There is also a tremendous need in this country for a better understanding of science and technology from the community that is served by science and technology. It is important, particularly at the secondary level, that there be good programs in science and mathematics for those who are not going to specialize in the field. I believe that a great deal more should be done to broaden the understanding of science and technology.

Mrs. HECKLER. Mr. Ryder, do you have concluding comments?

Mr. RYDER. I would certainly concur fully. I think that is part of the problem that we have not got the community understanding to give support at every level of the educational ladder.

I would say there has been an expressed concern about raiding. I think that is one of those areas that clearly calls for talking, communicating, and planning between education and industry. There are ingenious ways, I think, in which there can be reinforcement. One industry has given us $100,000 within the past year to serve as a fund to enhance the pay of a young engineering faculty member to be recruited so that he will not be brought over into industry but could stay at the university and serve effectively in the training of young people in that area.

Other types of assistance might include loaned personnel, sabbaticals in industry to give experience to faculty members, and also

enhancement of pay for periods of time. I think there are a number of things to be done. The important thing is let's talk together, and work together.

Mrs. HECKLER. I agree. I also would say there has been a great deal of good faith from the industry. No one has talked about the need for a change in curriculum and an emphasis at the earlier levels more eloquently than Mr. Henderson who published a paper and gave an address which I thought was superb on the subject. I think the Massachusetts High Technology Council is working on this as well. Obviously much more remains to be done.

If we are going to reverse the current trends of declining levels of science education in order to insure a scientifically literate America, we are going to have to make the right decisions in public policy.

There are many areas that I think would provide important related concerns from the committee and our counterparts on the local and State level.

Dr. Hollomon, I know we still have a difference of opinion and I would like to have your concluding comments.

Mr. HOLLOMON. I only have two comments. Number one is that I failed to introduce my colleague, Dr. John Hansen, who is currently responsible for the studies in my center on the supply and demand for engineers. He is a graduate of the Yale School of Economics which has been recently recognized in the press, and he has previously been doing supply-demand studies for a New England small company, Charles River Associates.

He is now responsible for trying to understand this discussion, not about elementary and secondary schools but about the supply and demand of engineers, generally.

Mrs. HECKLER. I would like to say that I feel that the question remains one that is subject to further examination. Given the time constraints today it is not possible to have every argument fully addressed.

I think the subject is so serious and so important that each panelist will have the opportunity to provide a fuller explanation of points of view for the record.

I thank the panel very much.

Mr. HOLLOMON. One other comment. The engineering faculty of educational institutions are, in fact, relative to industry, underpaid. Universities simply do not have the money to raise salaries in order to compete with industry.

If we did raise salaries, that money would have to come out of tuition. Then we have the cyclic phenomena. If we raise tuition, we put up further bars to the entrance of people to our institutions.

I believe the only way to deal with this difficult problem is to increase the productivity of the faculty. First, and I see a risk in saying this I think that faculty production can be increased. Second, it is not currently being done. While the productivity of the country continues to raise, albeit slowly, the productivity of universities remains approximately constant.

Mrs. HECKLER. Dr. Gray is not here?

Mr. HOLLOMON. That is why I say I take some risk.

I do believe that there are ways in which the productivity of teaching in the colleges and universities can be improved but very

little is being done in this direction. Do you know how much R. & D. money I spent to improve the institution of which I was president? None. Here is a strange thing. Here is a great institution—a whole industry of great institutions that does not do R. & D. to improve itself. If we need help from the Government, there is where we need it to try to understand how we can improve the efficiency of teaching at the college and university level.

Mrs. HECKLER. Sir, would that not be an appropriate subject for your Center for Policy Alternatives?

Mr. HOLLOMON. Well, we are in the business of raising such questions, not answering them. [Laughter.]

Mrs. HECKLER. Four stars for integrity. Dr. Hollomon, I have enjoyed this very much. I want to say to all of the panelists you have been very interesting and thoughtful in your statements and provocative in the questions raised. The issue will have to be considered at another forum. Unfortunately time constrains us today. I do welcome the input from all of the panels, from all of the members of the panel and from all participants and indeed the audience today on the issues that have been raised so that we can consider them fairly and equitably in Washington.

Thank you.

We have one final witness who has been listening all morning and we certainly applaud his patience as well as his contribution. I would like to call Mr. Michael Rooney, president and founder of Boston Systems Office, Inc., a member of the Massachusetts High Technology Council, and a past participant in passports export assistance program.

Delighted to have you with us.

TESTIMONY OF MICHAEL ROONEY, PRESIDENT, BOSTON SYSTEMS OFFICE, INC.

Mr. ROONEY. Thank you, Mrs. Heckler.

To me the most important part of today's hearing is a sense of competition. What we have been discussing is perhaps the educational aspects of needing more engineers or the question of foreign competition; but to me basically the issue is competition and I generally focus on the foreign competition issue since inside this country we have—in a sense—a free economy.

I think that the issues of people, engineers, whether they be technical people like engineers or they be less technical people in the manufacturing area, will solve themselves once the money is there to pay for them. To witness this, one might look at a new private institution called Wang Institute which has come along just to solve some of the peculiar shortages of personnel that they felt various educational institutions could not provide.

We are a small company at Boston Systems Office. We have a small amount of business, total revenues of something like $2 million; about half our business is done outside the United States. You would think that a company with $1 million of international business could go to any bank. After all, $1 million is really a piddling amount of money. We are talking about billions of dollars in the venture capital community.

But we have no choice. We must deal with the First of Boston. The First of Boston is the only bank—and we have tried several others—the only bank capable of handling $1 million of financial activity. That is really a condemnation of our financial community, almost our way of life, that the First of Boston has a high tech division and an international division, and the high tech division understands us, but they cannot handle our foreign transactions. We have to do business with the international division which does not understand us but can at least do our financial transactions.

It is ridiculous. I do not mean to say Boston Systems Office having a revenue of $2 million is a bad thing. That is something like more than 5 years of greater than 50 percent growth. So I do not think it is bad for us. But just on a scale, I think we should have several banks to choose from.

This is true because the United States is basically an isolationist country, and if it continues, in my opinion, it will be the death knell of our way of life as we know it. Why do I say it? I guess I say this because if we continue to spend more than we earn, just like anybody else who spends more than they earn, eventually we will go out of business. We are doing that. We are spending more than we earn.

What is the solution? To me the solution is to reverse the process and sell more overseas, have a positive balance of payments. How do we do that? We compete effectively overseas. I think you ought to underline effectively.

Some areas now and in some ways now we have a net positive balance of payments; high technology exports, very good. We are involved in them. We have a rate of growth outside the United States of twice that inside the United States. Many other high tech companies face maybe not the same rates of growth, but they face very nice rates of growth and very nice business outside of the United States; but we, none of us, compete effectively.

At a time when the Prime Minister of Japan, Mr. Suzuki, was telling our Government that he cannot restrict the export of automobiles into our country, he was also saying that American companies cannot bid on an even basis for telephone and computer contracts inside Japan.

We have put up with various import duties, tariffs, various other forms of restrictions, various barriers; some of the barriers being direct government subsidies to businesses.

Japan is highly touted for that kind of thing, but, in fact, in our particular business, which is some of the leading edge of technology involved in microprocessor software and development systems, we find direct competition that is subsidized by government grants in practically every country in Europe that we deal with. We do quite nicely against them, but still we do not—we cannot go to the government and say please give us some money. Better yet, they do not even come to us and say please give us some money, or please let us give you some money.

I have been to Japan, and American firms do a lot of business there. We do it at a great deal of expense beyond what we do in any other country in the world. The Japanese Government is uninterested in Americans doing business there. There are many American companies that have outlawed Japanese people from

tours of their companies. What they do when they go through the company is they take all the information, the pictures they can; and then they go home and they do something with it.

On the theme of government's giving away cash grants. I am not really in favor of the Government of the United States giving cash grants to companies. I grant you if they came to me and said please take this $10 million, we would probably take it. I do not think that is a good way for businesses or governments to go on.

What I am proposing is that we stand up; we stand up as a country, as a government, as a series of trade negotiators and we say both with our words and our actions that if you are going to kick us, we are going to kick you back or we are at least going to walk away, and that we no longer put up with restrictive trade practices against us. I do not mean words about restrictive trade practices; I mean real examples.

If we suffer a lack of business in a certain area that is unusual when compared to other world markets, such as we do not do so much—we do not do this amount of high technology business in a particular country, then we should take action against that because obviously our products are competitive around the world.

I think that until we stand up, until we act in a more uniform fashion or perhaps in a fairer fashion to ourselves, we will suffer in the world market because we will have essentially anticompetitive practices used upon us as we are now.

Another thing we could do to act favorably toward business in general is to approach this problem of how do we do business overseas in a more business-like fashion.

If I read our export statistics correctly, there are two main areas that seem to be the leaders of our export openings, our export possibilities. One is agriculture, the other is high technology. There may be others but those are the two I have recognized most often.

I think we are doing a fair amount with agriculture already. Perhaps we are not doing as much as we can. With respect to agriculture, I just do not know the problems, not being a farmer.

With respect to high technology, we are just not. It is unusual, perhaps extraordinary, to find an official of the U.S. Government, more particularly the Commerce Department, that understands high technology, even the more normal parts of high technology. I am involved in areas that are relatively esoteric, so I do not expect everyone to understand those areas.

To understand normal components like computers, connectors, things like that that are in normal use today is something that I feel we have a right to demand of the Commerce Department. The Commerce Department should not only understand them but should go out and promote them. There should be in each of the various trade offices and consulates of the United States intelligence officers that would go in and find out about the financial and business community with respect to agriculture and high technology and other product areas that are deemed to be exciting as export potentials.

would be in a much more competitive sense or a much more competitive situation with respect to our foreign competitors who are getting the benefit of a variety of barriers both import and government assistance kinds of barriers.

I think in the interest of time, I will close my remarks at this time.

Mrs. HECKLER. Thank you very much. I want to say we would agree that much more has to be done to accelerate our exports and support them.

Do you have questions, Mr. Walgren?

Mr. WALGREN. No; no questions. Thank you.

Mrs. HECKLER. We do appreciate your patience also and the time you have spent with us today. The record will be open for comments from every witness and for anyone interested parties on the subjects raised.

Thank you all for attending today. The hearing is adjourned.

[Whereupon, at 1 p.m., the subcommittee was adjourned.]

APPENDIX

STATEMENT OF MALCOLM BALDRIGE

SECRETARY OF COMMERCE

BEFORE THE SUBCOMMITTEE ON SCIENCE,

RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BOSTON, MASSACHUSETTS

NOVEMBER 24, 1981

Mr. Chairman, I'd like to thank you and Congressman Gregg - and add a very special word of thanks to Mrs. Heckler - for inviting me to participate in these hearings on the importance of the high technology industry and the problems confronting it. I'm particularly pleased that we're in New England where plain speaking and common sense are the accepted patterns. In my view, the issues which this Committee is examining today are simply too important to permit anything else.

In order to understand what is happening in our high technology sector, I think one has to have a basic appreciation of what is happening in general to American industry in terms of its ability to compete in the world marketplace. That is, we must examine at the outset the question of whether the problems of the high tech industry are peculiar to it alone or are symptomatic of a broader set of issues.

What is happening is that the United States, despite the unrivalled size and scope of its production facilities, is facing competitive challenges of a magnitude that only a few years ago would have been unimaginable. This is as true for computers, aircraft, semiconductors, and other high tech areas as it is for steel and automobiles. Our share of world trade in manufactured goods, for example, declined from 25% percent

in 1960 to 18% in 1980, our lead in this area was lost to Germany and we may soon drop to third place behind Japan, and we can expect increasing trade deficits in 1981 and 1982.

Why has this happened? First, our rate of productivity growth has trailed that of our major competitors on a consistent basis over the past decade. Among the many reasons for this is inadequate investment in new plant and equipment, research and development, and human resources. Interest rates have been higher in the United States than in many of our major competitors, resulting in a reluctance by American industry to commit long-term funds borrowed at such high costs.

In addition, we have been affected by high inflation, the tendency of Americans to save less than the citizens of other industrialized countries, an appreciated dollar which makes our exports more expensive to buy, formal and informal barriers to trade maintained by other nations, and increased competition from industrialized as well as less developed countries. The latter, by moving into low and moderate technology products, are increasing the pressure on the industrialized ones to accelerate their development of high technology industries.

Though I don't want to underestimate the resilience of American industry, it's fairly obvious that unless we are willing to acknowledge that our problems are serious and are willing to

take corrective action, we risk further deterioration of our international competitiveness.

Against this background, our need to focus attention on technology intensive industries becomes increasingly clear. We are speaking of industries which have developed from a point where they accounted for 8.6% of Gross Business Product in 1960 to 11.6% in 1978 (the latest data available); industries in which total employment went from 5.8 million in 1960 to 8.1 million in 1978; industries which have recently given us a $30 billion trade surplus in high technology goods which is essential for offsetting deficits in lower technology products, oil, and other areas. Indeed, in 1978, the value of manufacturing output originating in technology-intensive industries amounted to $166 billion.

Though the figures I've cited may sound large in absolute terms, they seem less so when we consider that, in the past two decades, what was a 30% U.S. share of world trade in high technology goods has dropped to 20%. In terms of scientific instruments, we've gone from 30% to less than 15%; in telecommunications, from 30% to under 19%; in commercial aircraft, from 65% to 54%. If the increase in the numbers of patents granted to foreigners since the early sixties is any indication, our market share may continue to decrease in the years ahead.

This shrinking market share has ramifications beyond the possibility of fewer jobs. Our technological leadership has long been a source of national pride and a contributor to our international prestige in the political, diplomatic and military arenas. These advantages will undergo serious erosion if other nations no longer feel compelled to come to our shores to get access to the best and latest technology.

Many of the factors I cited earlier in terms of American industrial competitiveness in general are particularly at work in high technology industries - as are some special ones. I'd like to focus on three factors in particular.

First, our high technology industries may be placed at an unfair competitive disadvantage in the years ahead as other nations, in an effort to ensure favored treatment for their high technology industries, pursue policies which can be viewed as an interference in the operation of normal market forces.

For example, we are having extreme difficulty penetrating European markets in the telecommunications area as a result of their tariff and Government procurement policies. Moreover, the Japanese Government, which has already assisted its

computer industry through special tax incentives, direct financial assistance, and development of industry consortia, has now targeted telecommunications as a priority for development.

The second factor is technological diffusion. I think we need to recognize that the significance of new technologies for economic development depends upon the extent to which they are "diffused" - that is, adopted - throughout an industry or economic sector. Inadequate investment in new plant and equipment, brought about in part by economic uncertainty as well as some Federal regulations, has retarded innovation and the diffusion of new technologies.

I know that this is a matter of particular concern to this Committee. With your Committee's encouragement, we at Commerce are in the process of developing a Productivity, Technology and Innovation Program to identify and analyze barriers to productivity improvement in the private sector and to develop alternative policies for eliminating them. This is certainly a subject which I believe will continue to merit close Executive - Legislative Branch cooperation.

The third factor - and also one that requires ongoing scrutiny - is what I'll call the human resources factor. According to the National Science Foundation, we may have enough scientists to satisfy existing demand, except perhaps in a few subfields of physical and biological science, but we do have shortages of trained computer professionals and most types of engineers at all degree levels. We are not graduating many more engineers than we did in 1950 and more are going right into industry rather than pursuing graduate level study. In addition, increasing percentages of those who obtain degrees in engineering are foreign students, and, particularly disturbing, fewer qualified engineers will be available to serve as faculty members who are competent to disseminate new knowledge through teaching and publication.

I am sure that those who will testify after I conclude will be able to discuss the ramifications of this in greater detail, but I think that strong evidence exists that we have ignored -- and continue to ignore -- the economic importance of human resources. A series of recent studies suggest that our falling competitive advantage in foreign markets may derive in large measure from our under-investment in human resource. Most recently, the Bureau of International Labor Affairs suggested that the decline in U.S. trade performance since the 1960's, which I discussed earlier, is partially the result of differences in the national emphasis on the acquisition of

89-542 O—82——10

labor skills through education and training. Between 1963 and 1975, the U.S. share of the world's skilled workers has fallen from 29% to 26%. Internationally, we have dropped from second to seventh in the "skill endowments" of our workers. The result of these ominous trends is that the skill content of American imports may increase as American exports steadily lose their competitive advantage and share of the market.

The numbers show that this danger is very real. The unmet human resource needs in high technology industries in Massachusetts are particularly illustrative. Some studies show that in the Bay State alone, only 59% of professional-technical openings were filled in 1979 and that, if this trend continues, 5300 of an anticipated 13,200 openings will go unfilled during the period 1979 through 1982. Similarly, more than a third of the anticipated 12,000 openings for paraprofessionals and technicians will also go unfilled during the same period.

Studies conducted for the semiconductor industry point out the implications of these trends. They show, for example, that an additional electrical engineer is required to support an additional $1 million in semiconductor revenues; that for each additional $6 million in revenues, an electrical engineer with a Ph.D. is required. Therefore, when these jobs remain unfilled, we are losing sales, profits, and tax revenues.

To some degree, this problem is the result of normal market place behavior. Students enroll, quite understandably, in greater numbers in those programs which tend to reflect the highest entering salaries of graduates at that time. If these are not relatively high - as was the case for engineers during the economic downturn of the middle 70's - enrollments will be lower and the effects visible only in subsequent years, as we are seeing now.

Accordingly, it is clear we need an economy in which technology-intensive industries can plan for the future, educational institutions can develop curricula to meet industry's need for those skills, and students can plan their careers with some degree of confidence. We must recognize the need to integrate continuously new capital and human resources so as to produce new products with newer, more efficient methods. This need is particularly acute as we become a more knowledge intensive, service-oriented economy in which advances in productivity will come to depend more and more on our investment in human resources.

I believe the necessary Federal policies are already in place. The Administration's Economic Recovery Program is designed to increase our competitiveness and restore our economic strength. Its provisions for accelerated depreciation

allowances and a special 25% credit for incremental R&D should provide a powerful stimulus for expanding investment and increasing the proportion of GNP that is saved and invested. The new tax law also provides for larger charitable deductions for gifts of research property which is important for providing students and faculty with the latest scientific equipment.

But more can be done. Those of us in the Government who run large agencies must learn to use our resources far more efficiently than we have in the past. In Commerce we are doing just that. We have, with the concurrence of the Congress, rejected the idea of trying to pick particular technologies for development through Federal funding in favor of encouraging private sector initiative. In addition, we have recognized that our efforts must be tied to a comprehensive business analysis program that assures that the full range of complex and varied factors contributing to productivity growth are adequately considered.

Our Productivity, Technology and Innovation Program is designed to meet these needs. It will consist of efforts to help the Government assess the impact of Federal policies on industries, to highlight areas which are potential candidates for regulatory reform, and to identify impediments to effective business performance.

In other words, our goal is to complement the Administration's policy-making apparatus by providing better information on sectoral developments rather than, as in the past, trying to determine what business should be doing. If this Program is to have any chance of succeeding, its managers must - and will - have to develop an increasing appreciation of the human resource problems of the sort that have brought us all here today.

I believe this Program, through which we expect to gain a better understanding of the factors affecting productivity at the industry level can help policymakers, business and universities. As part of our program we will disseminate information on critical human resource shortages, and on best productivity practices. As appropriate, we will encourage cooperation between the public and private sectors.

Finally, I think it is essential that public and private training and educational institutions continue to maintain close liaison with private sector firms so they can sharpen curricula, provide job search assistance, and provide our work force with the necessary generic skills. I would prefer to see the dollars which firms are forced to spend on remedial training in reading, writing and arithmetic put to other use.

In this regard, I am very encouraged by the growing trend toward university-business cooperative arrangements which I hope will provide needed funds and skills for improving our competitiveness in high technology areas.

In conclusion, Mr. Chairman, I want to note that your counterparts in the Senate have also expressed considerable concern about the need - as one Senator put it - "to rejuvenate the reservoir of science and technology" in this country. I'm delighted that the Congress is focusing its attention on these problems and I'm particularly pleased that this Committee is playing its accustomed lead role. These hearings should contribute immeasurably to the public debate on what we as a nation need to do and, as always, I look forward to working with you, Mr. Gregg, and Mrs. Heckler. Thank you.

ADE Corporation
77 Rowe Street
Newton, Massachusetts 02166
Tel. (617) 969-0600 Telex 922415

STATEMENT BY W.A. BAYLIES, VICE PRESIDENT ADE CORPORATION
FOR HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY NOV. 24, 1981

Gentlemen:

The National Bureau of Standards is an outstanding, but unfortunately lonely, example of proper support by the U.S. Government of the American Semiconductor Industry. This industry's counterpart in Japan as you well know has long been considered a top-priority "sunrise" one. It benefits from a long term industry-government cooperative program aimed at pre-empting the U.S.'s present role as the world's principal supplier of advanced-design semiconductor devices. Two hotly-contested items in the industry are VLSI (Very Large Scale Intergration) and DRAM (Dynamic Round Access Memory) devices. These are principal elements in the computer industry, at which the Japanese have aimed another newly announced cooperative development program. These devices also demand the utmost in performance from the high-technology material characterization, fabrication, assembly, and test equipment used to produce them, which is over $1 Billion in the U.S. This semiconductor equipment industry is quite probably the next area to be closely contested.

The characterization of materials entering the semiconductor process, and determining the effects of a multitude of

production processing steps involving such diverse areas as high temperature corrosive chemical treatment; high speed photolitographic printing of vanishingly by small features; high volume computer controlled packaging operations; and incredibly complex electrical testing throughout the process - all are necessary to create today's "leading-edge technology" devices.

The National Bureau of Standards provides an important service to material equipment and device manufacturers through its Semiconductor Technology Program. It would more properly be called the Semiconductor Measurement Technology Program. This program concentrates on those issues which would be impractical for private industry to pursue - where if NBS weren't involved, the industry would have to duplicate the work many times over, an inefficient use of high-cost investment/development funds. The present $5 million/year expenditure in this program saves the industry between 10 and 100 times that amount; and there are documented cases available from NBS showing a 50:1 benefit cost ratio.

The following examples highlight important on-going work:

Standard Reference Materials - as the keeper of all basic standard measurement references, NBS provides a unique service in extending the reference data into semiconductor technology. Bulk resistivity SRM's allow

users to accurately judge independent equipment performance in measuring this most basic of semiconductor material properties. In the near future programs to develop primary references for sub-microscopic defects such as trace amounts of Carbon and Oxygen in Silicon, and for practically invisible surface defects will be mandatory to support our country's drive for more sophisticated semiconductor devices.

Precise determination of line width - at the microscopic levels endemic in VLSI and DRAM work - has been an increasing industry-wide problem. Accurate line-width measurement is important to assure that purchased photomasks meet specifications and that the dimensions of integrated circuit elements conform to design values. Before NBS work was available to the industry, errors in measurement of 3 micrometer-width lines of as much as 35 percent were encountered.

NBS has invested about 20 staff-years in developing necessary physical understanding of the optical physics of the measurement and in developing the techniques for making the measurement. A standard reference mask-like artifact is now available for calibrating optical line-width measuring instruments.

Over 30 U.S. companies have bought this reference artifact and have revamped their in-house measurement methods. At least two large companies have discovered systematic erros of 0.1 to 0.2 micrometers in their in-house measurement systems and have gone to considerable effor to correct them.

Representatives of nearly 100 U.S. companies have received hands-on training in five technical seminars that NBS has given to transfer line-width measurement. Instruments have been re-designed to incorpororate NBS results. NBS can make line-width measurements on masks with a precision of 0.01 micrometers and an absolute accuracy of 0.05 micrometers on lines as small as 0.5 micrometers wide. These results can be duplicated in the field by industrial users to within a factor of two. The measurement is non-destructive.

The unique NBS contribution is made possible by the presence at NBS of the National Standard of Length and the expertise required for the work.

Because NBS has done this work, it does not have to be repeated by individual companies each of whom would have had to make a comparable investment.

NBS is continuing this work to provide the means to measure line-width on silicon IC wafers. This measurement is a more difficult physical problem but the theoretical understanding of the measurement is about 80 percent complete at present.

For your reference, a human hair is about 100 micrometers thick. Presently IC line-widths range down to one fiftieth of this width in production and down to one 200th of this width for the DOD VHSIC Program Phase 2 Goals.

Lastly, NBS provides valuable liason with other technical organizations to maximize for the industry the benefit of their measurement technology programs. This liason also insures that NBS understands the true nature of emerging industry requirements. They further provide liason with foreign standards orgnizations such as DIN in Europe which are usually closed to U.S. industry's direct participation.

As vice-chairman of ASTM's F-1 Committee on Electronics, and as chairman of SEMI's Standards Committee, I personally have seen NBS's unique technical expertise benefit the important work of these organizations. As an equipment producer I have seen their work improve our products' concept, performance, and development time. Their operating funds should not be reduced - they should be increased.

ADE Corporation
77 Rowe Street
Newton, Massachusetts 02166
Tel (617) 969-0600 Telex 922415

BIOGRAPHY: Winthrop A. Baylies, Vice President of Marketing

Winthrop A. Baylies, vice president of marketing at ADE, joined the company as a pioneer employee and manager of the sales department in 1971.

His most recent previous experience had been with the Axion Corp., Danbury, Conn., as vice president of marketing; Microtec Electronics, Cambridge, Mass., as sales manager; and with The Sippican Corp., Marion, Mass., as sales manager.

Following graduation from Harvard with an A.B. in physical sciences, Baylies served for two years with the U.S. Army. Upon completion of his military obligation, he joined the quality control department of Polaroid and later worked in sales and marketing for the Aerovox Corp., New Bedford, Mass., and Laboratory for Electronics, Cambridge, Mass.

Baylies maintains an active involvement in a number of high technology associations. He is a director of the Semiconductor Equipment and Materials Institute (SEMI), and serves as chairman of both its Standards Committee and Wafer Dimension task force. He is also a liaison member for SEMI with the American National Standards Institute (ANSI) where he is a member of the photovoltaic steering committee.

For the American Society for Testing and Materials (ASTM), Baylies serves as vice chairman of a committee on electronics, and is an author of several test method specifications for ASTM. He is an ASTM liaison member of the Deutsches Institute für Normung (DIN) in Berlin where he is a member of that group's subcommittee on testing of semiconductor inorganic materials.

Baylies resides in Weston, Mass. He and his wife have four college-age children.

DIMES

DRUG INTAKE MANAGEMENT AND EVALUATION SYSTEM, INC.
71 Elton Avenue, Watertown, Massachusetts 02172
(617) 926-1260

November 20, 1981

Congresswoman Margaret Heckler
1 Washington Street
Wellesley, MA 02181

Dear Congresswoman Heckler:

Unfortunately, the designation "high technology industry" has failed to achieve an interpretation much beyond "computer manufacturer." I would suggest that we will soon face the problem that sophisticated hardware is abundant while the number of applications for modern computing and communication technology is relatively sparse. In your attempts to focus "attention on the concerns and problems of high tech companies," I would applaud efforts to assure that those companies seeking ways to apply recent technology are viewed as major components of the high technology industry.

In our own particular case, DIMES has created an expert information base on psychopharmacology which can be directly applied to improving the safe, effective use of this most widely prescribed class of drugs. (One good estimate says that three of every ten Americans are prescribed a psychoactive medication in a six month period). "High technology" provides us the procedures to transfer information in a clinically meaningful way to large numbers of people. However, we have not been able to obtain the support from public regulatory and administrative agencies necessary to achieve widespread application. I am sure other companies seeking to distribute beneficial services through the use of modern technology have also not received the attention afforded to companies falling into the more narrow high tech definition.

Your attention to the needs of our industry is greatly appreciated, and I hope your focus is not allowed to narrow.

Sincerely yours,

Richard A. LaBrie
President

mn

SIGNATRON®
(617)861-1500
SIGNATRON, Inc. · 12 Hartwell Avenue · Lexington, Massachusetts 02173

TESTIMONY FOR CONGRESSIONAL HEARING
House Subcommittee on Science, Research and Technology
24 November 1981
MIT, Kresge Auditorium

Submitted by
Dr. Julian J. Bussgang
President
SIGNATRON, Inc.
Lexington, MA

My name is Julian J. Bussgang. I am President of SIGNATRON, Inc. a small high technology company, located in Lexington, MA. I was a delegate from Massachusetts to the 1980 White House Conference on Small Business. I have also been active in various innovation task forces and in the Innovation Committee work of SBANE (Smaller Business Association of New England).

The purpose of my testimony is to draw attention of this Committee to the importance of the National Science Foundation, Small Business Innovation Research Program. I believe that this program, directed by Mr. Roland Tibbetts of NSF, has contributed materially to speed up advancement of high technology. I can best illustrate it from my own experience.

Our company, SIGNATRON, Inc. was awarded a $25,000 grant under the SBIR program in 1980 for the development of a device that could substantially improve the quality of hearing aids and thereby help millions of the hard-of-hearing. Based on the promising results of our Phase I SBIR program we were awarded this year $125,000 as the Phase 2 program. Under the second grant we intend to demonstrate a prototype device. If the results are as impressive as we hope for, we intend, as Phase 3, to commercialize our invention. Since we believe that our device will also have many other commercial, voice-related applications, we hope that the development we are pursuing

will create new jobs and new exports.

My reason for describing this personal experience with the NSF SBIR program is to attest that without this program we would have probably never undertaken the development of this new technology and, that if undertaken at all, it would have proceeded at a much slower rate.

By way of explanation, our company has been active primarily in defense contract research. Over the twenty years of its operation, SIGNATRON has developed an enormous amount of electronics high technology with potential commercial application. However, it has been only the NSF SBI program that has enabled us to actually select and address at least one specific product application. I know that at this time, Congress is scrutinizing all Government expenditures. Agencies such as NSF, that are not delivering a direct operating service are particularly vulnerable. The objective of reducing the budget has certainly reached various NSF programs. We are told, for example, that in this International Year of the Handicapped, even the programs for the handicapped, which include the hard-of-hearing, have been dramatically curtailed. For this reason your committee should take note that such cuts will have a direct impact on future technology.

It is still too early to tell whether our own project will succeed in full. However, we do have high expections. I also know that all the other SBIR programs have been very carefully selected and show great promise. It is because of this conviction and this experience, that I want to testify at today's hearing.

I urge that you continue a vigorous innovation program as embodied in the NSF SBIR. An investment of public monies in such a program is an investment in the future of American high technology and ultimately in the overall health of the U.S. economy.

I urge that Congress support the NSF SBIR program in their budget deliberations.

Plan For Action To Reduce Engineering Shortage... With Supporting Data

By Pat Hill Hubbard
Manager, Engineering Education
October, 1981

American Electronics Association

89-542 O—82——11

Planting The Engineering Seed Corn

"Academicians compare industry's appetite for BSE graduates to that of starving American Indians of long ago who, to survive the winter, ate the seed corn needed to plant next year's crop."

INTRODUCTION

The American Electronics Association's 1981 Board of Directors appointed a select group of industry executives and educational leaders to a Blue Ribbon Committee on Engineering Education. The committee's charge has been to study the problem of engineer shortages, certify its existence and degree, identify the major barriers, and recommend a plan for Association action.

On September 15, 1981, AEA's Board approved the following nine-point plan for both short- and long-term redress. A white paper, which outlines the significance of the problem and points toward major causes, is included to provide a philosophical framework to view the direction of remedy the Association will take.

Because of the changing nature of the problem, industry will need to work to solve it for the "long haul." Other areas will clearly need attention down the way. For example, although an adequate supply of qualified engineering students now exists, changing demographics will cause a reduction in the applicant pool and a change in its composition to include more females and minorities and fewer white males. Increased career counseling and math and science "outreach" programs, therefore, will need to be aimed at females and minority high school students. Moreover, the increasing shortage of math and science teachers at the secondary school level, already at a danger point, will predictably reach crisis stage if something does not turn it around soon.

There is engineering seed corn still in the U.S. silos. The electronics industries just need to make a decision to pay the high cost to buy and plant it.

Pat Hill Hubbard, Manager
Engineering Education

One of America's fastest-growing and most economically-prized high technology industries is electronics. Young and dynamic, electronics has had a phenomenal annual growth rate of 17 percent during the past decade.[1] Sales of electronic products by 100 of the major companies reached $152 billion in 1980,[2] bringing the total sales for the larger industry close to $200 billion. A 1981 Panel on Computing and Higher Education quotes a Commerce Department report that says information technology accounts for 46% of the GNP, and computer sales alone bring a $6 billion balance of trade surplus.[3]

The promise of electronics to continue improving the quality of life is threatened by the growing shortage of computer software (CS) and electrical/electronic (EE) engineers. Like critical pieces of technological DNA, engineers are the building blocks of electronics.

TABLE OF CONTENTS

	INTRODUCTION	ii
I	AEA ENGINEERING EDUCATION PROGRAM	1
	Program Goal	1
II	EXTENT OF ENGINEERING SHORTAGE	6
	Statement of the Problem	6
	Supply and Demand	6
	Costs to Industry	8
	Defense Dollars	8
	Solution Dollars	9
III	CAUSES OF THE ENGINEERING SHORTAGE	10
	Statement of the Causes	10
	Attitudes	10
	Declining Birthrates	11
	The Undergraduate Supply	11
	Foreign Students	12
	Increase in Undergraduate EE and CS Degrees	13
	Decrease in Graduate EE and CS Degrees	13
	Limitations of Education's Capacity	13
	Outdated Equipment	16
	Outdated Facilities	17
	State Action	17
	The Most Critical Problem - Faculty Shortages	18
	The Doctoral Recruitment Pool	18
	Industry-Academia Salary Inequities	19
	Non-Financial Teaching Incentives	19
	Severity of Faculty Shortages	21
	Projected Shortfall of Faculty	21
IV	EFFECT OF CONTINUED SHORTAGES	22
	Economic, Political and Social Impact	22
V	VIEWS ON THE SHORTAGE	23
	References	iv
	Addendum A	vii
	Addendum B	viii
	Addendum C	ix
	Addendum D	x
	Addendum E	xi
	Addendum F	xii

I

AEA ENGINEERING EDUCATION PROGRAM

PROGRAM GOAL: To significantly increase the quantity of engineers while maintaining educational quality.

Problem Statement: An increasing national shortage of engineers threatens to limit the growth of high technology and negatively impact the economic and political leadership of the United States, as well as the continued health and expansion of the electronics industries.

Extent of the Problem: A shortfall exists between supply of engineering graduates and projected industry demands for engineers. The shortfall for the electronics industries alone projects to 25,000 EE/CS baccalaureate engineers annually through 1985. Engineering colleges will need to step up output immediately to meet the needs.

Causes of the Problem at the Undergraduate Level: The shortage of BS degrees is primarily due to a lack of resources, especially faculty, of engineering colleges to handle the oversupply of qualified students.

Degree of Undergraduate Problem: Roughly, only 1 of every 3 qualified applicants is admitted to undergraduate engineering programs because of limited resources. Enrollments, while up 7.2% from a year ago, are straining educational capacity, threatening the quality of education, and lessening the attractiveness of teaching as a career. In response, many colleges are limiting or contracting enrollments, raising admissions requirements, increasing class sizes, etc.

- Laboratory equipment, now 20 to 30 years old, is outdated and in short supply; little is available to teach "new technologies."
- Lab and classroom facilities need upgrading and are in short supply; increased numbers of students will create extra "wear and tear."

- o 10%-to-15% or 2,000 to 2,500 engineering faculty positions are unfilled. Faculty vacancies are nearly 50% in solid-state electronics, computer engineering, and digital systems. Faculty shortages make teaching unattractive (larger classes, longer hours) and affect educational quality.

Causes of the Problem at the Graduate Level: The shortage of MS and Ph.D degrees awarded to U.S. citizens is due to an undersupply of graduate students. After the BS degree students are attracted to jobs with high starting salaries in industry. Incentives to become faculty members (requiring Ph.D) are poor.

Degree of Graduate Problem: 400 fewer MS/EE degrees were granted in 1980 (total of 3,740) than in 1970 (total of 4,150). 350 fewer Ph.D/EE degrees were granted in 1980 (total of 532) than in 1970 (total of 873).

U.S. citizens received 76.5% or 2,859 MS/EEs awarded in 1980.
U.S. citizens received 67.4% or 352 Ph.D/EEs awarded in 1980.

- o Rising tuition costs, low graduate assistance salaries, fewer graduate fellowships, and inadequate facilities make BS-level industry salaries much more attractive than graduate study.
- o There are actual disincentives to pursuing the education required for a faculty career: low academia salaries compared to industry's, high student-to-faculty ratios, poor quality research and teaching equipment, difficulty in gaining external research funding, etc.

What Needs To Be Done:

Short-term: Add resources to immediately expand educational capacity.

Long-term: Add resources to increase the number of Ph.Ds (to do advanced industry research and to become faculty for tomorrow's students) and enhance the quality of engineering education.

What AEA Can Do

1. Expanded educational resources

   A. Increase faculty
      - o AEA adjunct and visiting professors
      - o AEA teaching "chairs"
      - o AEA industry consultancies (salary supplements for new faculty)
      - o Legislative action to increase engineering and computer science faculty salaries (public universities)

   B. Increase and upgrade equipment and facilities
      - o AEA grants
      - o AEA equipment transfers
      - o Legislative action to increase equipment/facilities budgets (public universities)

II. Increase graduate student supply (more Ph.Ds)

   A. AEA graduate student fellowships

   B. AEA co-op programs

How AEA Can Do It (Mechanisms):

1. Set an industry-wide standard for giving resources to education: 2% of a company's R&D expenditures.

   Such resources can be given directly by the company to the college or through an AEA foundation. They can be given in a variety of ways: equipment, industry facilities, adjunct/visiting professors, teaching "chairs," graduate fellowships, general grants of money, etc.

2. "Spotlight" model industry-university programs to encourage companies to duplicate them.

3. Form regional task forces composed of AEA Council Engineering Education (EE) Committees to work with companies and area colleges.

The engineering shortage is a national problem. Engineering colleges produce graduates who are employed all over the United States. The mobility question, however, is also focusing increased interest on area or regionally-located engineering institutions.

AEA's 13 Councils provide a unique organizational structure for addressing the problem from both a local and a national standpoint. Ten states produce 58% of the BSEs (all categories). Four of these "top 10" have AEA Councils.

Council EE Committees can work with local companies to provide industry personnel as part-time and/or full-time faculty for area universities and encourage them to provide additional resources to universities (money to fund teaching "chairs," graduate fellowships, etc.).

4. Provide assistance to the regional task forces with loaned industry executives as "facilitators."

With assistance from AEA Engineering Education staff, loaned industry executive facilitators can assist AEA Council EE Committees in various ways, such as: (1) identify the specific needs of the universities for faculty (background, experience, specialty teaching areas, etc.); (2) help AEA member companies identify and release qualified persons to teach part-time or full-time as the need may be; (3) set up interviews for selection by the schools; (4) assist fund-raising efforts to provide salary supplements/"chairs," graduate fellowships, etc. In states targeted by AEA for legislative activity during 1982, loaned executives can assist AEA's Engineering Education and Government Affairs staffs to identify issues and generate grass-roots support as well as industry input to state governments.

5. Set up an AEA Electronics Education Foundation (EEF) to publicize and promote the Engineering Education Program (records of resources given to education, etc.); to advise and assist companies opting to directly provide resources and undertake programs (promote 1-to-1, company-to-school relationships); and to accept and disburse resources as requested.

6. Continue the Blue Ribbon Committee on Engineering Education into 1982 to complete present planning, make the federal government and the Office of the President aware of the problem and the need for supportive fiscal and tax policies to solve it, and to provide "transition" of program guidance to a Standing Committee.

7. Establish an AEA Standing Committee to provide assistance to Engineering Education staff and general guidance in achieving program goals. It will report periodically to the Board to make recommendations as appropriate.

8. Establish industry lobby-networks in major electronics states to identify and support issues which will help meet program goals (increase state budgets for equipment, etc.).

9. Increase Engineering Education Department staff with 1 full-time position to assist in program management. Staffing and additional travel to facilitate regional task force directions require an addition to current budget.

II

EXTENT OF THE ENGINEERING SHORTAGE

STATEMENT OF THE PROBLEM

The growing shortage of engineers on a national scale threatens to limit the growth of high technology and negatively impact the continued health and vitality of the United States on economical, political, and social levels.

SUPPLY AND DEMAND

The American Electronics Association's recent nation-wide survey, "Technical Employment Projections: 1981-83-85," brings hard data to certify the existence of an engineer shortage (Figure 1 is based on the survey results and indicates the severity of the problem). Note that while the SUPPLY figures are from all U.S. colleges, the DEMAND data is only from the electronics industries.

The DEMAND figures were calculated by using the survey projections as a baseline. The 671 respondents represent $77.7 billion annual sales and 500,000 employees. As this baseline represents approximately one-third of the U.S. total, the figures were multiplied by 3 and compounded annually by 4.98% to account for losses due to promotion into management.[4] The DEMAND reflects new growth only and does not include replacements due to retirement, turnover, or death.

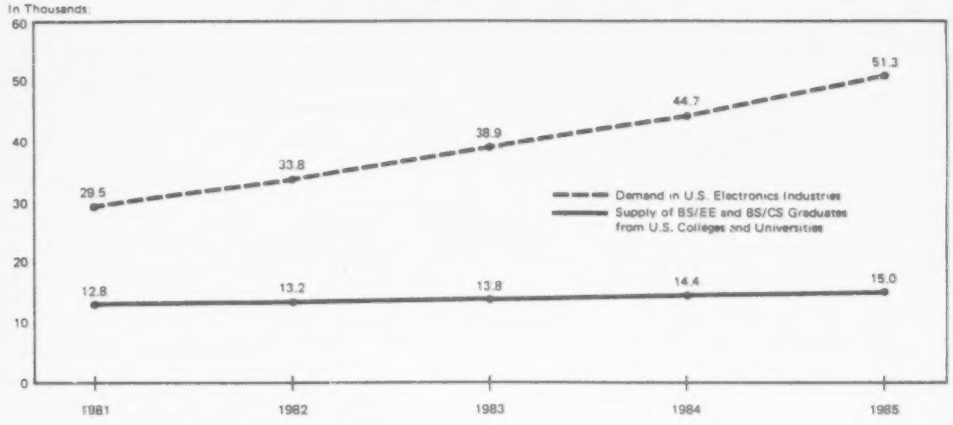
The SUPPLY figures were made by using the number of BS degrees awarded in 1980 as baseline.

The BS/EE projections were made using a 2.6% annual compounded growth rate (ACGR) projected by the U.S. Bureau of Labor.

The BS/CS degree figures were reached using a 12.4% ACGR, duplicating a pattern of 1977-to-1980 degree increases. All degree projections were reduced by 20% to account for graduates who do not take jobs in engineering.[5]

U.S. ELECTRONICS INDUSTRIES

COMPARISON OF PROJECTED SUPPLY AND DEMAND ELECTRICAL AND COMPUTER ENGINEERS



DATA: AMERICAN ELECTRONICS ASSOCIATION ©

Figure 1

By 1985 the electronic industries' total DEMAND for new BS/EE and CS people projects to be approximately 199,000.

By 1985, total SUPPLY of BS/EE and CS graduates projects to be around 70,000. Assuming electronics industries--to the exclusion of all other engineering-intense industries--can aggressively capture all the graduates, the SUPPLY shortfall by 1985 projects to be around 129,000 or 25,000 annually.

Just to meet the needs of electronics, education must triple its output of EE and CS engineers each year for the next five years.

Strong demands are validated by other measures as well. Deutsch, Shea, and Evans show no let-down in demand for more than three years:

YEAR	ENGINEERING RECRUITMENT INDEX
1978	139
1979	144
1980	138
1981	140 (Average of Jan. & Feb.)

One Fox-Morris survey showed demand for EEs leaped 18.5% during 198[illegible].[5] Another survey by the same group indicated the need for experienced programmers capable of writing applications software jumped 27.3% since mid-1980.[7] The American Society for Engineering Education (ASEE) estimates employers will compete heavily for 1981 engineering graduates; by diploma time, 75% with BS degrees, 73% with MS, and 92% with Ph.Ds will already have jobs.[8]

COSTS TO INDUSTRY

In the wake of the shortage there is a scramble for technical talent which escalates the cost-of-doing-business. The price for search firm location of a $30,000 engineer can be as high as $10,000. And the practice of offering finder's fees has increased. Loral Electronics, for instance, pays $5,000 for referral of an engineer with four years experience. Three Lockheed divisions pay employees $1,000 for each engineer they refer.[9]

Small companies, unable to offer perquisites such as tennis courts and jogging tracks, and who cannot spend huge sums on media-splash advertising and recruitment campaigns are severely disadvantaged. Since innovation and accelerated job growth historically come from small companies, the effect of long-term shortages on them is of special concern.

DEFENSE DOLLARS

Engineering shortages pose a dilemma for defense contractors. President Reagan was recently asked by the press where he thought companies would find technical workers if his defense budget passed. His optimistic reply was to "give industry the money, and it will find the people."

Yet to win defense dollars, company proposals must demonstrate that competent technical talent is already on board or "at hand." A lack of engineers

prevents companies from bidding altogether. Some companies "bet-on-the-come" of a defense contract and unnecessarily stockpile people. This practice compounds the shortage problem.

Companies which now have defense contracts are experiencing difficulty in staffing existing vacancies. Rockwell, with 17,000 engineers on the payroll, is looking to hire 900 more for 1981. A company representative expressed concerns about "losing....advanced men to retirement," noting that "quality field replacements are just about impossible to come by."[10] The Pentagon just announced that "because of a shortage of engineers at Vandenberg Air Force Base in California, there will be a 14-month delay in launching the first military payloads aboard the space shuttle."[11]

With high interest rates compounding some sky-priced rental and housing markets, the old formula of moving in large numbers of people to fulfill defense contracts is no longer a given. States like California find the mobility question quite serious. AEA survey data from 313 of the state's 3,500 electronics facilities shows a need through 1985 for new EE/CS level people of 20,557 or 4,111 per year.[12] A state agency's in-house analysis of the new national defense budget's effect determined that 700,000 new jobs---half in manufacturing--are likely to be created in California by 1986 (140,000 per year). Juxtapose these DEMAND figures against the 2,909 EE/CS graduate degrees (all levels) awarded by all public and private colleges in the state in 1980, add the mobility issue, and the problem's magnitude grows.

SOLUTION DOLLARS

Data analysis emphasizes the present shortage of engineers is likely to be exacerbated in the next few years unless industry intervenes. A study of the causes points strongly toward a money-solution.

Simply throwing a "few bucks" towards education in scattered directions brings short-term returns but may have negligible effects on the larger problem. Dollars given to colleges which lack understanding of the expanding need for engineers, whose presidents may reduce the engineering departments' budgets equal to the amount of industries' gifts, help shore up the educational system, but do not affect the problem at hand.

III

CAUSES OF THE ENGINEERING SHORTAGE

STATEMENT OF THE CAUSES

Currently, the shortage in BS graduates is caused by a lack of resources--most seriously in faculty--of universities to educate the oversupply of qualified engineering graduates.

The shortage in MS and Ph.Ds is caused by an undersupply of graduate students resulting primarily from high BS-level industry salaries and disincentives to enter teaching careers, not only limiting industry's progress in advanced research, but clearly reducing the pool from which future faculty come.

ATTITUDES

Some industry people view the cause of undergraduate engineering shortages as a misallocation of resources by university presidents. Why, they ask, don't presidents shift money from declining disciplines like English and move it to expanding ones like engineering?

Education responds to the query in several ways. Some oppose resource shifts because they consider the shortages temporary. Some are unwilling to increase engineering education budgets because of the industry's "fair-weather-friend" behavior. Some are unwilling to fight the institutional pressures involved in terminating tenured professors. And some fear increased engineering budgets will unbalance curricula and jeopardize their status as "comprehensive" universities, even when industry provides the additional monies.

Some educators look at the cause of the graduate student shortages--the pool from which future faculty come--as a result of myopic behavior by industry. Academicians compare industry's appetite for BSE graduates to that of starving American Indians of long ago who, to survive the winter, ate the seed corn needed to plant the next year's crops.

DECLINING BIRTHRATES

If all these philosophical resistances reverse, one economic constraint remains. Declining birthrates predict a substantial decrease in post-secondary enrollments by 1990 (See Addendum A). In 1988 there will be 2,130,000 (14.3%) fewer high school students than in 1980. A decrease in college enrollments means no tuition revenue increase to pay for great shifts of student career interests.

THE UNDERGRADUATE SUPPLY

A decade ago, engineers laid off due to space and defense program cut-backs became a media cause-célèbre. Year-long reports emphasized job losses. Rarely was the public's perspective balanced with information that the unemployment rate for engineers reached only 3.2%, staying but "a brief time before returning to its normal level of about 1%."[13] The public's long memory of the engineering "bust" coupled with Vietnam's anti-technology legacy, therefore, caused young people to avoid engineering careers for several years. This is no longer true. Engineering is the second most favored career choice of today's high school seniors (see Addendum B, Figure 1).

Estimates of the applicant-to-admission rate is placed at about 3-to-1. Dr. Joseph Pettit, President of Georgia Institute of Technology and a member of AEA's Blue Ribbon Committee on Engineering Education, states that his college approves admission for about 1,700 of the approximately 7,000 applicants. Dr. Richard Atkinson, Chancellor of UC San Diego and also a member of the AEA Blue Ribbon group, notes the high quality of today's engineering applicants and says his university, like most others, closes admissions doors the day they open. Dr. Jay Pinson, Dean of Engineering at San Jose State University, states he has "a thousand students 'holding' in other departments, waiting for engineering slots to open."

The schools have accommodated increased numbers of students. Full-time engineering undergraduate enrollments in the nation's 287 engineering colleges and universities are up 7.2% in undergraduate and 7.1% in graduate classes in fall of 1980 from a year ago. Freshmen undergraduate engineering enrollments

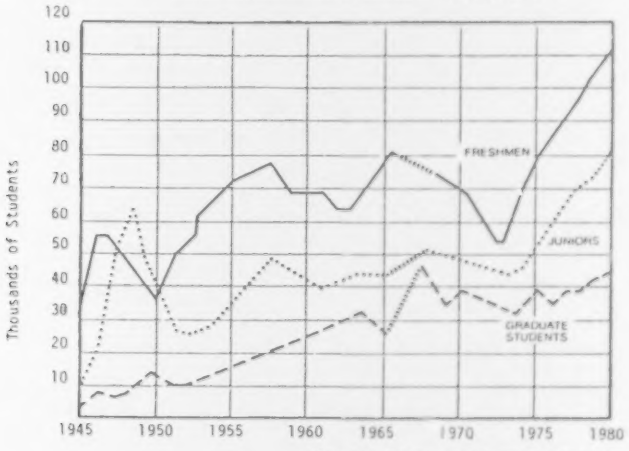
increased 6.2% from the previous year. Females and blacks accounted for 14.1% and 5.1% respectively of the freshman class increase.

FOREIGN STUDENTS

Some concern over increased numbers of foreign students in U.S. schools may be warranted in light of the numbers who return home after graduation and the pressure their added numbers place on already strained educational resources. In 1979, 260,000 foreign students were enrolled in postsecondary educaton (64% in public institutions). That number represents a 300% increase since 1964[14] In 1980, 6.8% of the engineering undergraduates were foreign students, while 46.3% of the engineering graduate students were foreign students. The increase of foreign students at the graduate level--from 38.7% in 1974 to the present 46.3%--does signal a need to do two things: increase the number of U.S. citizens who pursue graduate study and/or initiate federal policies which allow foreign graduates to remain in the U.S.

The recent jump in engineering enrollments at all levels, however, comes primarily from U.S. citizens--not foreign students. From 1979 to 1980 foreign student undergraduate numbers increased only 0.3% and graduate enrollments only 2.4%. Foreign students in all engineering education fields in 1980 were 40,774 or 9.4% of the total 433,451.

ENGINEERING FULL-TIME ENROLLMENTS 1945-1980



Source: Engineering Manpower Bulletin 58, May 1981
American Society of Engineering Education

INCREASE IN UNDERGRADUATE EE AND CS DEGREES

Since 1977 when BS/EE degrees dropped to 9,837, the lowest number since 1970, there has been a steady increase in EE and CS degrees. (See Addendum B, Figure 2 for EE and CS degrees awarded 1970-1980/all levels):

Year	BS/EEs Awarded	% of Change	BS/CSs Awarded	% of Change
1970	11,291	4.80%	139	167.31%
1971	12,145	1.88%	174	25.18%
1972	12,430	2.35%	359	106.32%
1973	11,844	-4.71%	568	58.22%
1974	11,347	-4.20%	727	27.99%
1975	10,277	-9.43%	599	-17.61%
1976	9,954	-3.14%	796	32.89%
1977	9,837	-1.18%	1,280	60.80%
1978	10,702	8.79%	1,546	20.78%
1979	12,213	14.12%	1,510	-2.33%
1980	13,594	11.31%	1,816	20.26%

2,303 more BS/EEs were awarded in 1980 than in 1970, an increase of 20.4%

DECREASE IN GRADUATE EE AND CS DEGREES

At the graduate level the data reflects a reverse trend. 490 fewer MS/EEs were awarded in 1980 (3,660), or 11.8% less than the 4,150 in 1970. 350 fewer Ph.D/EEs were awarded in 1980, (523) or 40% less than 873 in 1970.

Comparing EE graduates of all levels in 1977 with those in 1970 on a per capita basis, a decrease is evident.

1970 88 EE graduates per one million U.S. population
1977 66 EE graduates per one million U.S. population.[15]

The sales of electronics products over the last 20 years has increased six times. The number of EE graduates has only doubled. An increase of only 5% more EE degrees at all levels has taken place during the last decade: 16,944 in 1970 versus 17,777 in 1980.

LIMITATIONS OF EDUCATION'S CAPACITY

Some people point to the recent engineering enrollments as a sign the shortage is easing. Indeed the percentage of degreed BS/EEs has been rising for the last three years. In 1980, for example, 13,594 BS/EE degrees were awarded--an 11.3% increase over the previous year.

Assuming the 11.3% degree-growth pattern holds steady for the next five years, 94,793 BS/EE degrees would be awarded between 1981-1985. Since only 80% (75,834) is likely to enter the workforce as engineers, these numbers are still a considerable shortfall to the projected DEMAND for 199,000. (See Figure 3.)

It takes four-to-five years for an engineering student to receive a bachelor's degree. To determine the relationship between total engineering enrollments (all fields) and the number of BS/EE degrees granted requires that current degrees awarded be compared with enrollments at least four years previously. The 13,594 BS/EE degrees awarded in 1980, for example, represents 1 degree recipient to every 25 enrollees or 4.0% of the total 337,801 enrollments four years ago.

BS/EE DEGREES IN RELATION TO ENGINEERING ENROLLMENTS ALL FIELDS

School Year	Engineering Enrollments All Fields	Enrollment Increases Over Previous Year All Fields	BS/EE Degrees Awarded/Year	Engineering Enrollments in All Fields Four Years Previously	% of BS/EE Degrees to Enrollments Four Years Previously
1975/76	309,553	31,566	9,954--1976	270,153	3.7%
1976/77	337,801	28,248	9,837--1977	263,003	3.7%
1977/78	374,182	36,381	10,702--1978	277,987	3.8%
1978/79	396,594	22,412	12,213--1979	309,553	3.9%
1979/80	433,451	36,857	13,594--1980	337,801	4.0%
1980/81	469,929	36,478	[15,130--1981*]	374,182	see note A
1981/82	[580,450**]	[110,521**]	[16,840--1982*]	396,594	see note B
1982/83	[646,050**]	[65,600**]	[18,743--1983*]	433,451	see note C
1983/84	.....	.....	[20,861--1984*]	469,929	see note D
1984/85	.....	.....	[23,218--1985*]	[580,450**]	[4.0%**]

Notes:

Brackets [ ] indicate projections.

*Degree-projections are based on 11.3% annual growth.

**Engineering enrollment projections assume continuation of the 4% relationship of BS/EE degrees to enrollments four years previously.

Note A: 15,130 degrees at a 4% relationship of degrees-to-enrollments requires enrollment four years previously to have been 378,250. The actual enrollment of 374,182 leaves a 4,068 student shortfall already.
Note B: 16,840 degrees at 4% requires enrollment of 421,000. 396,594 actual enrollment leaves 24,406 shortfall.
Note C: 18,743 degrees at 4% requires enrollment of 468,575. 433,451 actual enrollment leaves 35,124 shortfall.
Note D: 20,861 degrees at 4% requires enrollment of 521,525. 469,929 actual enrollment leaves 51,596 shortfall.

Assuming that the relationship of BS/EE degrees as a percentage of engineering enrollments in all fields continues as it has in the past few years, and taking the high point as 4.0%, enrollment will need to reach 580,450 in the coming school year in order to award 23,218 BS/EE degrees in 1985 (at 11.3% annual BS/EE growth). This will require an increase of 110,521 students. (See Figure 3.)

Unless substantially more engineering students choose electrical engineering majors or unless more who now major in it get degrees, maintaining an 11.3% annual increase of BS/EE degrees will require annual enrollment increases ranging from 65,000 to 110,000.

These increases are unlikely for two reasons. One is history. The largest enrollment increase in the past five years occurred between school years 1978/79 and 1979/80 -- 36,857. As a recent article in the Wall Street Journal notes, engineering schools are "already at capacity" and "crowded schools can't increase enrollment further....some are even cutting back."[16]

The second is demographics. Declining numbers of high school students over the next decade (see Addendum D) will reduce college enrollments, making even the present 36,000+ increase a challenge to maintain.

The strain placed on educational resources by extra numbers of students sets up a "capacity" factor. This "educational bottom line," combined with a diminishing high school population, makes the Bureau of Labor Statistics' 2.6% projection for EE degree-growth understandable and calls for caution in thinking enrollment increases alone are going to provide an answer.

Increasingly educators voice concern as the extra students push resources beyond capacity. They warn that a decline in quality may result.

A 1980 University of New Orleans (UNO) study of 100 engineering schools provides insight into the enrollment-quality relationship (see Addendum C, Figure 1). 66% of the respondent schools felt enrollment was so high that it posed an immediate problem and handled it in a variety of ways.

* 45% (23 out of 51) increased the GPA requirements for transfer students

* 37% (21 out of 56) increased the GPA required of new students entering engineering
* 13% (6 out of 44) increased the prerequisite classes - upper or lower division
* 71% (28 out of 39) reported taking no steps to limit enrollment.

A Western Interstate Commission for Higher Education (WICHE) survey of 15 western engineering schools recently revealed that "most will have to limit enrollments within the next few years; a few of the larger universities are already operating under legislatively imposed university-wide enrollment ceilings."[17]

The present situation in engineering undergraduate education is characterized by plenty of students, but too few resources to educate them without risking a loss in quality.

OUTDATED EQUIPMENT

John Fluke, President of John Fluke Manufacturing and a member of AEA's Blue Ribbon Committee, recently commented that on a visit to his alma mater he found some of the lab equipment he had trained on fifty years ago still in use.

According to an ASEE assessment, the engineering teaching equipment found in most university labs is 20-30 years old and equipment to teach new "growth technologies" is almost non-existent.[18] New technological processes, demanding sophisticated and costly equipment, have sky-rocketed the cost of teaching laboratories. Ohio State estimates installation of modern design equipment at $3 million plus 15% annual maintenance.

The Association of Independent Colleges estimated in 1978 that calculating 6.5 years as the useful life of instructional equipment, $1,500 per year per engineering baccalaurate degree would be needed to keep equipment up-to-date.[19] Applying this formula to last year's BS/EE graduates brings the annual price tag for electrical engineering teaching equipment alone to $20 million.

A distinction should be noted between research and teaching equipment money sources. Grants and contracts largely pay for research equipment.

Academic budgets and industry gifts are a primary source for instructional equipment. Few colleges can afford expensive CAD/CAM and integrated circuit technology teaching equipment and students will graduate without training in these important areas.

Industry requires modern equipment to compete in the marketplace with state-of-the-art technology. As a result, the "ivory research towers" are on industry land today and attract students who might formerly have chosen graduate study and even teaching careers.

OUTDATED FACILITIES

Like equipment, most engineering labs and classrooms are now 30 years old. Federal money to build facilities has come in pennies over the last 20 years.[20] Inflation, OSHA regulations, and laws requiring building accommodations for the handicapped have compounded universities' inability to provide money for upgrade, repair, or expansion of their teaching plants.

STATE ACTION

A few states are awakening to the resource shortage within their public postsecondary schools. They have begun funneling state funds into engineering education.

* University of Wyoming is spending $18 million on engineering facilities expansion.
* New Mexico recently funded a new engineering building at New Mexico State University and allocated $5 million a year for upgrading science and engineering at all state universities.
* At Arizona State University a five-year $32 million dollar program to establish an electronic and computer "center of excellence" by adding new facilities, equipment and a 63% faculty increase is in process.[21]
* The North Carolina General Assembly just allocated $24.4 million for the construction of a micro-electronics center. The North Carolina center will draw resources from five universities, a community college system, and the Research Triangle's private industries.[22]

* California budgeted $2.6 million to improve UC Berkeley's Cory Hall for micro-electronics instruction.

Nationally, however, much remains to be done. ASEE estimates it will take about $40 million per year to update lab equipment and modernize classrooms.[23]

THE MOST CRITICAL PROBLEM - FACULTY SHORTAGES

Though too-little-too-old equipment and facilities are blocking an "increased throughput" of engineering students, the most serious current bottleneck is the faculty shortage.

Of the nation's some 20,000 engineering faculty jobs, 10% to 15% or 2,000 to 2,500 are presently unfilled. In fields such as solid-state electronics, computer engineering, and digital systems, NSF's Stephen Kahne places the shortage closer to 50%.[24]

Why are people turning away from teaching? Why, for instance, did only 8% (13 out of 160) of the new Stanford Ph.Ds choose teaching last year versus an estimate of 50% ten years ago?[25]

THE DOCTORAL RECRUITMENT POOL

The student doctoral pool from which faculty traditionally comes is shrinking. Only very dedicated U.S. students and foreign students who know "they need higher degrees to compete with citizens for the same jobs"[26] go on to graduate study.

Foreign students are an increasing percentage of the EE doctoral pool. Of the 523 Ph.D/EE degrees awarded in 1980, 171 (33%) went to foreign students. Of these, 66% were on student visas and likely to return home.

ENGINEERING Ph.Ds
PERCENTAGE OF FOREIGN STUDENTS

1964 = 19.8%	1977 = 41.5%
1974 = 38.7%	1978 = 45.0%
1975 = 41.3%	1979 = 45.6%
1976 = 42.3%	1980 = 46.3%

Source: National Science Foundation

The majority of foreign students "are of very high caliber, among the best their country has, and graduate in the top fifth of their class."[27] Yet those who wish to remain in the U.S. face a six month to two year immigration process. Cultural and language differences pose an additional challenge for those who enter teaching.

INDUSTRY-ACADEMIA SALARY INEQUITIES

Economics plays a significant role in faculty shortages.

BS graduates lack incentives to continue their education. Graduate assistant salaries average only $4,500 to $5,000 today. Rising tuition, housing and food costs, and the scarcity of fellowship monies (NSF's 1982 budget all but wipes them out) combine with the knowledge that "a young graduate can start at $5,000 more than his old teachers."[28] Few can resist industry's starting salaries of $20,000 to $24,000.

A 1980-81 ASEE Faculty Salary Survey shows the following average nine month salaries:

Professors	$33,295
Associate Professors	$25,793
Assistant Professors	$21,758
Instructors	$15,903

The UNO study (see Addendum C, Figure 2) reveals essentially the same salary pattern and further shows a relationship between salary and size of school.

Several years of doctoral study and five or more years of teaching must occur before academia's salaries become economically interesting--and then rarely more so than industry's.

NON-FINANCIAL TEACHING INCENTIVES

Money has never been the sole reason people choose to teach. The opportunities to do research and promote growth of knowledge in students in a comparatively relaxed atmosphere have been strong attractions.

Research contracts have always been a prime faculty perquisite. NSF research contracts can provide up to 2/9ths of a salary supplement. For

most other types of research contracts and grants, many universities allow up to one-third of the annual nine-month salary. Grants are becoming increasingly difficult to obtain.

As a percent of GNP, industrial R&D spending decreased from 2.1% in 1964 to 1.6% in 1979.[29] In spite of the investment downtrend, R&D spending at universities and colleges was up 3% in 1972-constant-dollars during 1979. Much of it, however, was not spent in idea generation or product development. It was spent meeting governmental and environmental regulations. Data from the center for the Study of American Business shows that the effect of increased government regulations on the cost-of-doing-business rose from $2,240 million in 1974 to $4,823 million in 1979.[30]

Teaching loads, commonly reduced to permit research, are becoming heavy. The University of New Orleans data (See Addendum C, Figure 2) shows the relationship between research and teaching loads. UNO respondents:

36% teach 9-to-11 hours a week
31% teach 12-to-14 hours a week

77% have reduced teaching loads to do research
52% receive 1-to-3 hours reduction
46% receive 4-to-6 hours reduction
22% responded that research was not a basis for a reduced load.

Academia's former "more relaxed atmosphere" has also been supercharged by high student-to-faculty ratios. For quality education, a ratio of 1 faculty to 20-25 students is considered ideal.[31] The UNO study show that only a few classes remain within the optimal range. (See Addendum C, Figure 3 In small schools of 500 or less students, the faculty-to-student ratio reaches as high as 1-to-118; 500 to 1,500 student schools as high as 1-to-51; 1,500 to 2,000 student institutions up to 1-to-48; and large schools of 2,000 or more 1-to-39.

Outdated and scarce facilities and equipment, insufficient R&D, increased teaching laods and high student-to-faculty ratios have diminished the non-financial incentives. A climate now exists where pay inequities make the final difference.

SEVERITY OF FACULTY SHORTAGES

Almost 94% or 75 of the UNO respondents (see Addendum C, Figure 1) answered "Yes" to the question: "Are you experiencing difficulties in recruiting new, qualified faculty?" Engineering faculty is clearly a scarce commodity.

In June 1980 Dr. John Kemper, Dean of Engineering at UC Davis, surveyed 241 ABET-accredited engineering schools to quantify present and projected faculty shortages. He found 1,800 current faculty vacancies and 335 new openings due to retirement and 380 new vacancies for projected expansion per year. From 1981 to 1990, therefore, 7,525 new openings--an average of 750 per year--will be needed just for retirement and expansion.

Dr. Kemper adds 180 each year to "work off" current vacancies and finds the annual need for new engineering faculty to be 980 per year.[32]

PROJECTED SHORTFALL OF FACULTY

Based on present trends, what is the projected annual shortfall of the teacher supply?

Approximately 2,700 Ph.Ds in engineering are awarded annually. Generally, 1,300 of these go to foreign students. 33% of these Ph.Ds have temporary resident status[33] and are likely, because of growing sensitivity to the American "brain drain," to return home.

The pool of U.S. students and foreign ones who remain after graduation comes to about 2/3 of the total degree recipients, or 1,800 people. Whereas in the 1960's 1-out-of-3 Ph.Ds went into teaching, today only 1 in 4 does.[34] Applying this 25% formula to the 1,800 suggests a supply of only 450 new faculty each year.

Dr. Daniel Drucker, Dean of College of Engineering at University of Illinois, Urbana-Champaign, says the supply is actually smaller, less than 300, since "quality instruction of undergraduates requires selection from among the upper third (or higher) of all Ph.Ds."[35] Whether 300 or 450 are available, the shortfall to the needed 1,000 is still large.

Assuming that 2/3 of the total Ph.D engineering graduates continue to enter U.S. employment and that they return to the 1-out-of-3-who-choose-to-teach formula, we will need to increase the supply of doctoral-level engineers by 1,300 each year (to a total of 4,000 doctoral graduates) to receive the needed 1,000 faculty.

IV

EFFECT OF CONTINUED SHORTAGES

ECONOMIC, POLITICAL, AND SOCIAL IMPACT

The United States is still the most productive country in the world. Yet while others improve their ratio of output-per-worker, America does not--dropping from a WWII 2.9% increase to a minus 0.9% in 1979.

Japan's productivity makes U.S. industries jog faster to run the economic mile. On a per capita basis, Japan has fewer than 1/20th the lawyers, 1/7th the accountants, but 5 times as many engineers as the United States.[36]

The Soviet Union's double time to reach "scientific and technological supremacy"--graduating 6 times as many undergraduate engineers as the U.S.[37]--causes discomfort in America's national defense arenas.

According to a 1977 NSF study, high technology has twice the productivity, triple the real growth, six times fewer price increases, and nine times more employment when compared to low technology industries.[38] Electronics in particular holds the promise of winning on the economic, political, and social fronts--if the engineer shortages are reversed.

> "The lack of electronic and computer science engineers may be the single most important factor limiting the growth and continued vitality of electronics industries."
>
> Dr. William Perry, Partner, Hambrecht & Quist
> Former U.S. Undersecretary of Defense for
> Research and Engineering

V

VIEWS ON THE SHORTAGE

A variety of views on the shortages of engineers has been expressed in professional associations and trade journals. A consensus is forming. Stephen Kahne, Director of the Division of Electrical, Computer, and Systems Engineering at the National Science Foundation (NSF) puts the matter into perspective:

> It is no longer an open question whether the shortage of electrical engineers in the United States is or is not a crisis. It is. Sooner or later every U.S. industry dependent upon electrical engineering will be affected--and there are more such industries now than ever. Toy and automobile manufacturers, even textile and clothing companies, have discovered the value of electronics and computer-based systems in their products or manufacturing processes. Indeed, these new industries, previously unaffected by electrical engineering in any significant way, are the hidden factor that invalidates traditional market surveys of future needs for EEs. It is hard to predict the growing need for electronics specialists in sectors of the economy that never before employed them.[39]

REFERENCES

[1]Ray Stata, President and Chairman, Analog Devices, Inc., "Needed: A Plan for Educating Engineers." Electronics, April 24, 1980, p. 26.

[2]"The Electronic Business 100." Electronic Business, February 1981, p. 64.

[3]Robert G. Gillespie, Vice Provost for Computing with Deborah A. Dicaro, Research Associate, University of Washington. Computing and Higher Education: an Accidental Revolution, 1981, p. 5.

[4]Electronics industries' annual percentage of promotion of exempt employees into management established by survey of AEA Industrial Relations Committee, 1980.

[5]Estimated by National Science Foundation and American Society for Engineering Education.

[6]Quote by Walter V. Nichols, Vice President of Fox-Morris Personnel Consultants, San Francisco. Electronic Design, September 1980.

[7]"Briefs: Information Processing." Business Week, August 3, 1981, p. 68F.

[8]Scientific, Engineering, and Technical Manpower Comments, Washington, D.C., June 1981, p. 5.

[9] Wall Street Journal, July 14, 1981, p. 1.

[10] John Radick, "Firms Vying for Scarce Engineering Talent," Electronic News, June 15, 1981, p. 40.

[11] Gerald F. Seib and Roy J. Harris, Jr., "Defense Tactics: In Military Buildup, Big Contractors Face Supplier Bottlenecks; Where Are the Engineers?" Wall Street Journal, August 21, 1981, p. 11.

[12] Technical Employment Projections Survey: 1981-83-85. American Electronics Association, Palo Alto, California, June 1981, p. 76.

[13] J. D. Kemper, Dean of Engineering, UC Davis, "Graduate Enrollments in Engineering; Meeting National Needs for Productivity," July 1980, p. 9. Source reference: Quarterly Unemployment Rates for Engineers Released, Engineering Manpower Highlights, Pub.No. 225, Engineers Joint Council, New York, November 1972.

14 Stephen Kahne, NSF Presentation, May 7, 1981. Slide No. ECS 81-1756, 4-1-81.

15 The International Microelectronic Challenge. The Semiconductor Industry Association, Cupertino, California, May 1981, p. 29.

16 Roger Lowenstein, "Two-Edged Sword: Surge in Engineering Enrollment Begins to Ease Industry's Shortages but Stirs Trouble at Colleges." Wall Street Journal, August 20, 1981, p. 48.

17 "Can Higher Education Meet the Need for Technical Manpower?" WICHE Reports. Summer, 1981, p. 11.

18 Ward Worthy, "Chemical Education Falls on Hard Times." C & EN, February 9, 1981, p. 45.

19 Task Force Chaired by Robert H. Page, Texas A&M University, "Data Related to the Crisis in Engineering Education." March 1981, AAES, ASME, ASEE, p. 11.

20 Issues in Engineering Education, a Framework for Analysis, Task Force on Engineering Education of the National Academy of Engineering. Washington, D.C., April 1980, p. 13.

21 WICHE, p. 12.

22 "Micro Center Gets $24.4 Million From Legislature." Future State, Mark Ernsberger, ed., First Union National Bank, Charlotte, North Carolina, August 1981.

23 Worthy. C & EN, p. 45.

24 Stephen Kahne, National Science Foundation, "A Crisis in Electrical Engineering Manpower." IEEE Spectrum, June 1981, p. 50.

25 Summary, Meeting of the Engineering Manpower Task Force, Business-Higher Education Forum, St. Louis, Missouri, April 7, 1981, p. 3. American Council on Education, Washington, D.C.

26 "Wanted: U.S.-born Graduate Students." Chemical Week, June 24, 1981, p. 45.

27 Ibid., p. 46.

[28]Trends: "The Vanishing Professor." Forbes, July 20, 1981, p. 8.

[29]"The Problem: The Decline in U.S. Productivity." Business Week, June 30, 1980, p. 60.

[30]Kahne, Slide Presentation, 4-1-81. ECSE81-1049, 12-18-80.

[31]Wm. S. Janna, University of New Orleans, "The Enrollment Crunch: A National Survey." Engineering Education, April 1981, p. 706.

[32]Kemper, "Graduate Enrollments In Engineering," p. 8.

[33]NSF and NRC, Summary Report, "Doctorate Recipients from U.S. Universities." 1979.

[34]"National Crisis: A Severe Engineering Faculty Shortage," Shakertown Conference, December 3 and 4, 1980, Pleasant Hill, Kentucky. Shakertown at Pleasant Hill, Kentucky, Inc., Harrodsburg, Kentucky, 40330, p. 1.

[35]Daniel C. Drucker, Dean, College of Engineering, University of Illinois at Urbana-Champaign, Statement before Subcommittee on Science Research and Technology of the Committee on Science and Technology, U.S. House of Representatives, March 3, 1981, p. 5.

[36]Claudia Deutsch. Business Week, July 6, 1981, p. 105.

[37]Catherine P. Ailes and Frances W. Rushing, "A Summary Report on the Educational Systems of the U.S. and the Soviet Union: Comparative Analysis." Prepared for NSF, SRI International, Final Report, March 1980, p. iii.

[38]"Revitalizing the U.S. Economy." Business Week, June 30, 1980, p. 103.

[39]Kahne. IEEE, Spectrum, p. 50.

ADDENDUM A

Summary of enrollment in educational institutions[1], with projections, by level of institution: Fall 1970 to fall 1988

Fall of year	Total enrollment	Elementary schools (Grades K–8)	High schools (Grades 9–12)	Institutions of higher education
		(In thousands)		
1970	59,899	36,686	14,632	8,581
1971	60,152	36,688	15,116	8,948
1972	60,000	35,569	15,216	9,215
1973	59,902	34,999	15,380	9,603
1974	60,340	34,584	15,532	10,224
1975	61,063	34,174	15,704	11,185
1976	60,587	33,766	15,727	11,012
1977	59,955	32,951	15,720	11,284
1978	59,948	32,861	15,628	11,259
		Projection		
1979	58,129	31,378	15,245	11,508
1980	57,382	30,974	14,797	11,611
1981	56,682	30,614	14,298	11,690
1982	55,695	30,217	13,808	11,670
1983	55,381	30,273	13,495	11,613
1984	55,122	30,208	13,422	11,492
1985	55,111	30,257	13,496	11,358
1986	55,232	30,675	13,402	11,215
1987	55,578	31,389	13,183	11,104
1988	55,938	32,223	12,667	11,048

[1] Includes public and private institutions.

NOTE: Details may not add to totals because of rounding.

SOURCE: U.S. Department of Health, Education and Welfare, National Center for Education Statistics, *Projections of Education Statistics to 1988–89*, 1980.

ADDENDUM B

Figure 1

Source: National Opinion Research Center

Reported in Manpower Comments, May, 1981, p. 26.

FIELD OF COLLEGE STUDY PLANNED BY HIGH SCHOOL SENIORS

	1980	1972
Business	22%	13%
Engineering	10%	5%
Health services	8%	12%
Preprofessional	8%	—
Education	6%	12%
Computer and information science	5%	2%
Social sciences	5%	17%
Art	4%	3%
Communications	4%	2%
Vocational or technical	3%	3%
Biological sciences	3%	10%
Agriculture	2%	3%
Architecture	2%	2%
English	2%	3%
Home economics	2%	2%
Music	2%	3%
Physical science	2%	3%
Foreign language	1%	1%
Mathematics	1%	2%
Philosophy or religion	1%	1%
Other fields	4%	0.5%

Figure 2 U.S. ENGINEERING GRADUATES

NUMBER OF DEGREES

ELECTRICAL ENGRS

YEAR	B.S.	M.S.	PH.D.	TOTAL
1970	11921	4150	873	16944
1971	12145	4359	899	17403
1972	12430	4352	850	17632
1973	11844	4151	820	16815
1974	11347	3702	700	15749
1975	10277	3587	673	14537
1976	9954	3782	644	14380
1977	9837	3674	574	14085
1978	10702	3475	524	14701
1979	12213	3335	545	16093
1980	13745*	3740*	523	18008*

* Errata sheet from Engineering Manpower Commission corrects 1980 BS/EE degrees to 13,594, MS/EE to 3,660, total all degrees to 17,777.

COMPUTER ENGRS

YEAR	B.S.	M.S.	PH.D.	TOTAL
1970	139	185	34	358
1971	174	250	44	468
1972	359	627	83	1069
1973	568	589	96	1253
1974	727	723	83	1533
1975	599	678	107	1384
1976	796	718	90	1604
1977	1280	802	136	2218
1978	1546	986	123	2655
1979	1510	1074	190	2774
1980	1816	1262	159	3237

ANNUAL % GROWTH

ELECTRICAL ENGRS

	B.S.	M.S.	PH.D.	TOTAL
	4.80	2.49	1.75	4.07
	1.88	5.04	2.98	2.71
	2.35	-0.16	-5.45	1.32
	-4.71	-4.62	-3.53	-4.63
	-4.20	-10.82	-14.63	-6.34
	-9.43	-3.11	-3.86	-7.70
	-3.14	5.44	-4.31	-1.08
	-1.18	-2.86	-10.87	-2.05
	8.79	-5.42	-8.71	4.37
	14.12	-4.03	4.01	9.47
	12.54	12.14	-4.04	11.90

COMPUTER ENGRS

	B.S.	M.S.	PH.D.	TOTAL
	167.31	54.17	54.55	84.54
	25.18	35.14	29.41	30.73
	106.32	150.80	88.64	128.42
	58.22	-6.06	15.66	17.21
	27.99	22.75	-13.54	22.35
	-17.61	-6.22	28.92	-9.72
	32.89	5.90	-15.89	15.90
	60.80	11.70	51.11	38.28
	20.78	22.94	-9.56	19.70
	-2.33	8.92	54.47	4.48
	20.26	17.50	-16.32	16.69

SOURCE: ENGINEERING MANPOWER COMMISSION

The Rosen Electronics Letter, December 31, 1980

ADDENDUM C

Figure 1

Engineering College Limits on Enrollment and Class Size, 1980.

College Enrollment Range	Enrollment Increases: 0-5%	6-10%	11-15%	16-20%	21-25%	over 25%		Enrollment Limitation—C: A	B	a	b	c	d	D	E	Average Class Size Limit: Type of Course	≤ 15	15-20	21-25	26-30	31-35	36-40	41-45	46-50	over 51
< 500	3	9	2	1	2	1	Y	13	12	2	1	1	14	16	18	Service		1	2	8	2	2		3	3
							N	8	7	7	10	8	2	5	3	Non		1	8	2	2	4	1	2	
500-1500	3	9	6		3	3	Y	18	15	8	9	2	6	15	22	Service				6	5	3		3	6
							N	8	11	10	10	14	5	11	1	Non	2	4	5	1	2		2	5
1500-2000	3	6	6	4	1		Y	11	15	7	5	3	4	15	21	Service		1	2	5	1	2	3	6	
							N	5	5	7	11	9	4	7	1	Non	3	7	2	2	1	4	3		
> 2000	1	7	2	1			Y	7	9	6	6	0	4	3	14	Service			2	2	1	1	2		
							N	6	3	4	4	7	0	7	0	Non	1	1	4	1		2	2		

A—Is this (the enrollment increases in the college) unusually high?
B—If appropriate, has the enrollment increase presented a problem which needed immediate attention?
C—Several questions on whether or not steps were taken to limit enrollment:
a) Increasing the GPA requirement of transfer students.
b) Increasing the GPA requirement of students entering engineering.
c) Raising the prerequisites of lower and/or upper level courses.
d) No steps were taken to limit enrollment.
D—As necessary, have new engineering positions been provided at your institution to maintain a "manageable" student faculty ratio?
E—Are you experiencing difficulties in recruiting new, qualified faculty?

Figure 2

Engineering Faculty Salaries, 1980.

College Enrollment Range	Average Teaching Load: 3-5 hrs	6-8 hrs	9-11 hrs	12-14 hrs	over 15 hrs		A	B: 1-3 hrs	4-6 hrs	Salary of Graduate Assistant 9-Month Contract: 30-35 K	35-40 K	40-45 K	45-50 K	50-55 K	55-60 K	65-70 K	over $7,000	Salary of Assist. Prof 9-Month Contract: 16-17 K	17-18 K	18-19 K	19-20 K	20-21 K	21-22 K	over 22 K	Salary of Assoc. Prof 9-Month Contract: 22-23 K	23-24 K	24-25 K	25-26 K	26-27 K	over 27 K
< 500	1		2	11	8	Y	9	7	4	2	7	1		1		1	1	1	6	3	6	3	2	3	6	7	2	2	2	1
						N	7																							
500-1500	1		6	9	10	Y	21	12	6	3	7	3	3		2			1	3	7	2	5	6	3	4	9	4	2	2	3
						N	5																							
1500-2000			12	5	5	Y	17	4	9	1	2	4	10	2		1	1	1		3	2	4	4	10	1	3	5	5	3	4	2
						N	2																							
> 2000	1		4	6	3	Y	9	3	4	1	2	1	3	4		1	2		1	1	3	2	2	3	1	3	1	1	5		
						N	2																							

A—Is research a basis for reduction in teaching load?
B—If so, how much of a reduction?
Note: Assistant and associate professor salaries are average starting salaries for an individual starting work in fall 1980.

Figure 3

Departments of Electrical Engineering, 1980.

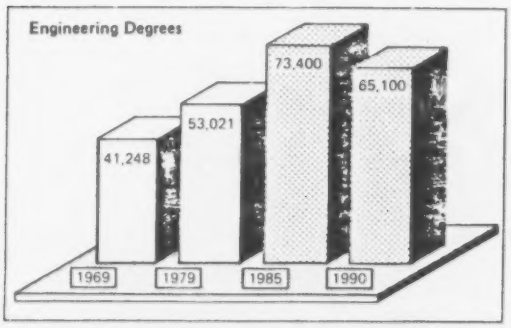
College Enrollment Range		Student/Faculty Ratio	No. of Faculty	Enrollment Increases: 0-5%	6-10%	11-15%	16-20%	21-25%	over 25%
< 500	Hi	118	30						
	Lo	8	4	2	5	4	2	1	2
	Av	25.2	10.6						
500-1500	Hi	51.5	19						
	Lo	11	4	5	3	5	2	3	
	Av	23.2	10.4						
1500-2000	Hi	48.4	38						
	Lo	5	9	2	8	1	6		4
	Av	20.1	20.7						
> 2000	Hi	39.9	100						
	Lo	13.7	4	1	6	2			2
	Av	24.0	44.5						

SOURCE: William S. Janna, University of New Orleans, "The Enrollment Crunch: A National Survey." Engineering Education, April 1981, pp. 706-707.

ADDENDUM D

"EFFECTS OF DEMOGRAPHICS ON ENGINEERING ENROLLMENTS"

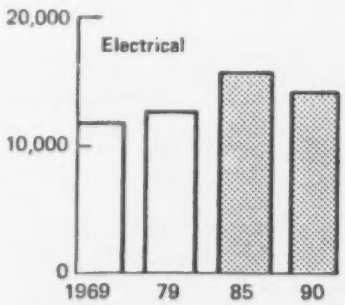
Chart 1--Total Bachelor's degrees in engineering



The projected increase in engineering degrees to 1985 reflects dramatic increases in engineering enrollments as documented by NCES[2] and the Engineering Manpower Commission.[3] The decline in 1990 reflects demographic changes -- decreases in the college-age population -- which are expected to impact at that time. The decline should result in degree outcomes that are lower than the 1985 projections for total engineering.

Source: National Center for
Education Statistics
February 13, 1981

Bulletin NCES 81-406



ADDENDUM E

AEA BLUE RIBBON COMMITTEE ON ENGINEERING EDUCATION

Committee Chairman
Dr. William J. Perry, Partner
Hambrecht and Quist

Dr. Richard Atkinson, Chancellor
University of California, San Diego

Dr. Joseph A. Boyd, Chairman of the Board and Chief Executive Officer
Harris Corporation

John M. Fluke, Chairman
John Fluke Manufacturing Company, Inc.

Dr. C. Lester Hogan, Director and Consultant
Fairchild Camera and Instrument Corporation

Dr. Robert N. Noyce, Vice Chairman
Intel Corporation

Dr. Joseph Pettit, President
Georgia Institute of Technology

Dr. Allen E. Puckett, Chairman
Hughes Aircraft

Ray Stata, Chairman and President
Analog Devices, Inc.

Dr. Dean A. Watkins, Chairman
Watkins-Johnson Company

Dr. Karl Willenbrock, Green Professor of Engineering
Southern Methodist University

John A. Young, President and Chief Executive Officer
Hewlett-Packard Company

ADDENDUM F

TOP 10 STATES AWARDING EE/CS DEGREES
1979 - 1980

State	Bachelor's	Master's	Doctor's	TOTAL
1. California	1,626	1,123	160	2,909
2. New York	1,621	609	73	2,303
3. Massachusetts	881	307	49	1,237
4. Pennsylvania	887	198	34	1,119
5. Illinois	750	289	64	1,103
6. Michigan	843	197	15	1,055
7. Texas	680	274	37	991
8. Ohio	640	279	33	952
9. Indiana	488	101	29	618
10. Missouri	507	82	21	610
Top 10 Total	8,923	3,459	515	12,897
U.S. Total	15,410	4,914	682	21,006
Top 10 Share of Total	58%	70%	76%	61%

SCHOOLS AWARDING THE MOST ENGINEERING DEGREES'
1979 - 1980

from Engineering Manpower Commission, 1980

ALL ENGINEERING DEGREES COMBINED

Bachelor's		Master's		Doctor's	
Purdue	1442	Stanford	770	MIT	162
U Illinois (Urbana)	1257	MIT	673	U Illinois (Urbana)	156
Penn State	1136	Cal Berkeley	571	Cal Berkeley	131
Texas A & M	1081	Poly Inst. NY	512	Stanford	110
Georgia Tech	985	U Michigan(Ann Arbor)	415	Purdue	91
U Michigan (Ann Arbor)	917	U Illinois (Urbana)	406	Cornell	82
U Missouri (Columbia)	794	USC	397	Ohio State	63
U Missouri (Rolla)	768	Geo. Washington U	317	USC	62
U Washington	766	Purdue	295	UCLA	58
Virginia Tech	762	Georgia Tech	294	Northwestern	53

EE DEGREES

U Illinois	293	Stanford	216	MIT	48
Purdue	275	USC	158	Stanford	33
MIT	270	MIT	151	USC	32
U Missouri (Col.)	254	Georgia Tech	109	U Illinois	32
Georgia Tech	237	Purdue	96	Purdue	25
U Washington	204	Poly Inst NY	91	UC Santa Barbara	21
Penn State	199	U Illinois	90	Cornell	15
U Minnesota	188	Rensselaer Poly	80	U Texas	11
U Texas	176	Ohio State	71	Ohio State	10
Virginia PI	171	Cornell	68	U Mo. (Columbia)	9
				U Syracuse	9

CS DEGREES

Cal Berkeley	256	Cal Berkeley	147	Cal Berkeley	31
U Illinois	118	Poly Inst NY	94	MIT	17
Oregon State	106	Northwestern	70	U Illinois	15
Texas A & M	87	U Michigan	[illegible]	Purdue	12
U Michigan	78	USC	[illegible]	Northwestern	12
Michigan State	73	U Pennsylvania	[illegible]	UCLA	11
UC San Diego	61	Ohio State	45	Princeton	11
Connecticut U	58	UCLA	44	Ohio State	10
Rensselaer Poly	52	U Illinois	41	U Washington (Mo.)	7
U Illinois	49	S. Clara U	40	Cornell	7
CC New York	49	U Oklahoma	40		

HIGH TECHNOLOGY EMPLOYMENT IN MASSACHUSETTS AND SELECTED STATES

LABOR AREA RESEARCH PUBLICATION

Massachusetts Division of Employment Security

job market research

CONTENTS PAGE

Acknowledgements . . . . . .

Introduction . . . . . .

Indexes of Manufacturing and High Technology Employment - Ten Largest Industrial States 1975-1979. . . . . .

Description and Sources of the Data

Standard Industrial Classification . . . . . .

Average Annual Wage . . . . . .

Employment and Wages Subject to U.I. Laws . . . . . .

Employment Data - Current Employment Statistics . . . .

Criteria for Selection of States . . . . . .

High Technology Employment, Massachusetts, United States, Selected States . . . . . .

Annual Average Wages in High Technology Industries . . . .

Summary Tables . . . . . .

TABLES

1. Total, Manufacturing, and High Technology Employment, United States, Selected States 1979. . . .

2. Total Employment Subject to Employment Security Laws, United States, Selected States 1975-1979 . . . .

3. Manufacturing Employment as a Percent of Total Employment, United States and Selected States 1975-1979 . . . . . .

4. High Technology Employment as a Percent of Manufacturing Employment, United States, Selected States 1975-1979 . . . . . .

5. High Technology Employment as a Percent of Total Employment - United States and Selected States 1975-1979 . . . . . .

6. Annual Average Wages in Total Employment, Selected States 1975-1979 . . . . . .

7. Annual Average Wages in Manufacturing, Selected States, 1975-1979 . . . . . .

8. Annual Average Wages in High Technology Industries, Selected States, 1975-1979 . . . . . .

ACKNOWLEDGMENTS

The survey staff of the Job Market Research Department of the Massachusetts Division of Employment Security wishes to express its gratitude to the Research Directors of the 24 states that furnished the information on which a major portion of this report is based. Without their cooperation and prompt response, this report could not have been completed.

Arizona
California
Connecticut
Colorado
Florida
Georgia
Illinois
Maine
Maryland
Michigan
Minnesota
Nevada
New Hampshire
New Jersey
New York
North Carolina
Ohio
Pennsylvania
Rhode Island
Texas
Utah
Vermont
Virginia
Washington

INTRODUCTION

Massachusetts has long been in the forefront of the development of new technologies and of technological changes. It is recognized that not all regions of the country are participating in such changes to the same degree or have reached the same stage of development. Certainly Massachusetts, with a long history of economic-industrial development, has one of the more advanced industrial bases. From the beginning, Massachusetts has participated in research and development of all facets of new technologies: new methods of production; new products and services; automated, computer controlled machine tools; plastics; new methods of surgery and surgical equipment; electronic equipment; use of nuclear energy; and space vehicles. A steady flow of new methods, new designs, new products, and new companies has come from the Commonwealth's educational complex.

The purpose of this study is to evaluate Massachusetts' position in relation to other industrial states, in particular those that are potential alternative sites for the burgeoning high-technology facilities. A large proportion of the Commonwealths' employment is in high-technology industries which make use of her highly skilled labor force and of the specialized educational and research services available to the industrial complex. This analysis is based on employment and wages in high technology, manufacturing, and total employment.

Summary of Findings

High technology industries have a solid base in Massachusetts.

Gains in manufacturing employment, in Massachusetts centered in high-technology sector, up over 32 percent from 1975 to 1979.

Most spectacular gains were in the manufacture of office and computing machines and electronic components and accessories.

Massachusetts continued to hold its share of United States manufacturing employment in each of the five years under review at the same time the proportion of United States high-technology employment rose year-to-year from 6.1 percent in 1975 to 6.5 percent in 1979.

Massachusetts compares favorably with other large industrial states in the increase in its share of United States high-technology employment.

Massachusetts, with the lowest population and total employment of the 10 largest states, ranks fourth in terms of employment in high-technology industries.

Massachusetts stands in first place among these states in the proportion that high-technology is of manufacturing in 1979.

Wages in high-technology industries stand above wages in manufacturing as a whole and far above the average for total employment.

1.

What Are High Technology Industries? While the term "high technology" has no formally accepted definition, most organizations in Massachusetts have been using a select group of 20 industries (3-digit standard industrial classification codes) for the past 10 years. The reason for using a prescribed set of SIC codes is that comparable data are available from all states and are consistentover time, thus providing a basis for comparison and analysis of the data with other states and other industry sectors.

The particular 20 industries (3-digit SIC) were selected after extensive discussion and analysis by the economists at Jobs For Massachusetts (JFM). In general, the companies classified in these industries are labor intensive, with a highly skilled employee base. In particular they have a high ratio of scientists and engineers to their total labor force. These firms are characterized by high growth rates, high ratios of research and development (R & D) expenditures to sales and have high value added products. Their products compete in World Wide rather than simply regional or national markets.

The 20 SIC codes include the following industry groups, all within the manufacturing sector:

Drugs (SIC 283) This group includes establishments primarily engaged in manufacturing, fabricating and processing medicinal chemicals and pharmaceuticals.

Ordnance and Accessories, NEC (SIC 348) This group is largely comprised of establishments manufacturing small arms, ammunition (having a bore of over 30 mm).

Office Computing and Accounting Machine (SIC 357) This industry includes electronic computing equipment, especially mini and small computers and related peripheral devices plus calculating and accounting machines.

Electrical and Electronic Machinery, Equipment and Supplies (SIC 36) Includes SIC's 361, 362, 363, 364, 365, 366, 367, 369 this major group includes establishments engaged in the manufacturing of machinery and apparatus for the generation, storage, transmission, transformation and utilization of electrical energy.

Guided Missiles and Space Vehicles and Parts (SIC 376) This group is principally engaged in the production of guided missiles and space vehicles including R& D activities.

Miscellaneous Transportation Equipment (SIC 379) Includes establishments primarily engaged in manufacturing vehicles for attachment to cars or other vehicles such as snow mobiles, caddy cars, etc.

Measuring, Analyzing, and Controlling Instrument photographic, medical, and optical gooos; watches and clocks (SIC 38) Includes 381, 382, 383, 384, 385, 386, 387 This major group includes establishments engaged in production of engineering, laboratory, scientific, and navigational instruments; measuring and controlling instruments; optical instruments; medical instruments/supplies; and photographic instruments and supplies.

This array of industries represents the manufacturing arm of high technology activities in Massachusetts and does not include the technical service companies engaged principally in educational, scientific and research activities.

Description and Sources of Data

All data series are classified in accordance with the Standard Industrial Classification Manual, 1972 Edition. As a consistent series of employment and wage data was not available for all states prior to 1975, comparisons are limited to the years 1975-1979.

Average annual wages detailed in the discussion and tableswhich follow are gross averages; included are wages for full and part-time work and for all grades and classes of workers. Also included are overtime pay, vacation allowances, bonuses, paid sick leave and the cash value of goods and services received by workers. The payroll data are, therefore, indicators of trends of relationships and do not represent actual average pay scale in the industries under discussion.

The wage data for high-technology industries may, however, by considered more representative of actual wage scales because they are not as heavily influenced by part-time schedules as are the seasonally-influenced nondurable goods and nonmanufacturing industries.

The employment and wage data submitted by the states is a compilation of information from employers' unemployment insurance contribution reports submitted to state employment security agencies. The data are coded to provide a distribution of employment and wages according to the industrial classification of the goods and services produced. Also included in total employment are data for Federal government installations.

The source of employment data for the United States is the Current Employment Statistics program, a joint effort of the cooperating states and the Bureau of Labor Statistics. Data on employment, hours and earnings are collected monthly from a sample of establishments in all nonfarm activities including government. From these data, series in considerable industry detail are published for the nation, states and areas. Wage data identical to that obtained from employers' contributions reports are not available for the United States.

The U.S. data in the study are published in Employment and Earnings, United States 1909-1978 Bulletin 1312-11 and Supplement to Employment and Earnings, September 1980.

Both series exclude estimates of employment and earnings for the self-employed, and unpaide family worker groups.

Criteria for Selection of States

The criteria for selection of the states included in this study were

1. States considered by the U.S. Department of Commerce, Bureau of the Census the 10 largest states, based on population and employment in 1970.

California	Michigan	Pennsylvania
Florida	New Jersey	Texas
Illinois	New York	
Massachusetts	Ohio	

2. The 17 industrial states, with which Massachusetts has been compared in the Social Contract between the Governor and selected High Technology Companies.

Arizona	California	Connecticut	Illinois
Maine	Maryland	Michigan	New Hampshire
New Jersey	New York	North Carolina	Ohio
Pennsylvania	Rhode Island	Texas	Vermont
Washington			

3. The following additional states with growing populations which are frequently reviewed as site location alternatives were included in the survey.

Colorado	Nevada	Virginia
Minnesota	Utah	

A questionnaire (see sample page) was mailed to the 24 state agencies listed above requesting annual average employment and wage data for the calendar years 1975 through 1979 for all industries subject to state unemployment insurance laws including for profit and nonprofit, federal, state, and local governments, manufacturing industries, and an aggregate of the high-technology industries described above.

High Technology Industries

Massachusetts and Selected States

High technology industries have a solid base in Massachusetts reinforced by such supportive facilities as great universities private technical research organizations and technically-oriented service establishments.

From her universities, laboratories, and factories come the most mind - boggling display of technological wizardry of which twentieth century science is as yet capable. It requires a new vocabulary to describe both the products and the jobs. One finds here are such varied products as inertial navigation systems, light measurement, laser systems for a variety of uses; small electronic consumer devices; electro-optical devices; optical encoders; systems planning systems as well as the ubiquitous main frame and mini-computer, to name a few.

Such developments are reflected in the growth in factory employment, concentrated largely in the high-technology sector. Massachusetts has experienced sharp gains and losses in manufacturing employment in the past. In fact an almost roller-coaster surge characterizes the decade of the 60's and the early 1970's. Since 1975, however, the upward thrust, concentrated largely in the high technology sector, has been outstanding.

MASSACHUSETTS

Industry Sector	Annual Average Employment	Percent Change 1975-1979
All manufacturing	671,700	+16.3
High-technology industries	222,000	+32.3
Other manufacturing	449,800	+ 9.7

As shown above the gains in the high technology industries outpaced the modest gains of the long-established nondurable, consumer-oriented factory industries which advanced by less than 10 percent compared with the overall gain of 32 percent in high-technology employment.

In the 60's and early 70's, the high technology industries were dominated by demand from the military-aerospace complex. As this demand lessened a compensating increase in demand for computers, instrumentation, and optical products, with the resultant upswing in employment has developed. Especially noteworthy is the five-year gain in employment in office and computing machine manufactures (SIC 357) which ballooned by nearly 90 percent from over 20,000 to nearly 40,000. The electronic and accessory component sector (SIC 367) also experienced robust gains in excess of 60 percent from 1975-1979.

The following table details Massachusetts manufacturing employment and employment in each of the 20 selected high-technology industry groups in the years 1975 through 1979.

TABLE A EMPLOYMENT IN ALL MANUFACTURING AND IN

HIGH TECHNOLOGY INDUSTRIES (3-DIGIT SIC)

MASSACHUSETTS

1975 - 1979

(Employment In Thousands)

INDUSTRY GROUP CODE and TITLE	EMPLOYMENT HI-TECH INDUSTRIES				
	1979	1978	1977	1976	1975
ALL MANUFACTURING	671.7	652.9	618.3	595.1	577.6
ALL HI-TECH. INDUSTRIES	221.9	206.2	190.6	172.8	167.7
283 Drugs	2.7	2.3	2.7	2.1	1.9
348 Ordnance & Accessories, NEC	5.0	4.9	4.9	4.6	4.1
357 Office & Computing Machines	39.6	31.3	27.6	21.6	20.9
36 ELECT. & ELECTRONIC EQUIPMENT	104.7	97.8	93.8	88.6	85.9
361 Elect. Distrib. Equip.	5.9	5.9Ø	12.3	13.2	12.8
362 Elect. Indus. Apparatus	6.2	5.7	2.7	2.6	2.3
363 Household Appliances	1.3	1.3	1.3	1.4	1.2
364 Elect. Light & Wire Equip.	9.0	10.1	9.5	8.7	7.8
365 Radio & TV Receiving Equip.	2.9	4.0	3.8	3.6	3.1
366 Commun. Equipment	29.5	27.1	25.0	25.5	28.6
367 Electronic. Components & Acces.	44.5	39.1	35.5	30.3	27.0
369 Misc. Elect. Equip. & Supplies	5.4	4.6	3.7	3.3	3.1
376 Guided Missiles, Space Veh. & Parts	12.1	12.1	11.8	11.0	10.9
379 Misc. Trans. Equip.	.2	.2	.2	.2	.2
38 INSTRUMENTS	57.9	57.7	50.4	44.8	44.0
381 Engin. & Scientific Equip.	3.3	3.2	2.9	1.8	2.7
382 Measure & Control Devices	18.2	17.8	16.2	14.2	14.2
383 Optical Instruments & Lenses	6.3	5.7	5.2	4.7	4.3
384 Med. Instru. & Supplies	6.5	6.8	5.3	4.5	4.3
385 Ophthalmic Goods	7.0	6.2	5.9	5.8	5.6
386 Photographic Equip. & Supplies	15.2	16.5	13.2	12.1	11.3
387 Watches & Clocks	1.4	1.5	1.7	1.7	1.6

* May not add to total because of rounding
Ø SIC Code change

NDUSTRIES AND AS A PERCENT OF MANUFACTURING EMPLOYMENT,
TATES AND SELECTED STATES

1975 - 1979

loyment in thousands)

1978		1977		1976		1975	
h	Per. Mfg. Emp.	Hi-Tech Emp.	Per. Mfg. Emp.	Hi-Tech Emp.	Per. Mfg. Emp.	Hi-Tech Emp.	Per. Mfg. Emp.
0	15.8	3,007.6	15.3	2,855.0	15.0	2,748.0	15.0
8	37.7	43.1	37.6	40.9	39.3	3,726.4	37.6
1	28.0	464.2	26.8	439.2	26.6	420.6	26.5
7	21.9	86.2	21.2	83.3	21.0	80.0	20.5
2	26.4	40.0	26.2	36.2	25.4	33.0	24.3
3	20.7	72.6	19.2	63.2	18.3	60.9	18.0
3	0.3	1.2	0.2	1.1	0.2	1.1	0.2
3	19.1	235.4	19.2	225.7	19.0	229.9	19.0
9	8.0	7.5	7.1	6.8	6.7	6.1	6.4
4	13.8	30.6	13.1	30.6	13.2	29.4	12.7
4	31.6	190.8	30.9	172.8	29.0	167.6	29.0
4	8.0	79.8	7.1	74.9	7.1	73.3	7.7
2	27.0	88.6	26.1	81.0	25.3	75.8	24.3
2	18.0	2.4	15.8	2.0	15.5	1.8	14.5
3	29.4	28.5	28.1	24.5	26.0	20.4	23.9
3	22.5	173.4	22.6	167.2	22.0	167.0	22.2
9	24.2	345.3	23.6	343.4	23.7	342.3	24.0
7	9.3	68.1	8.7	59.7	7.9	55.0	7.9
0	12.2	164.9	12.3	151.1	11.7	148.9	11.8
0	15.2	197.5	14.6	199.9	14.9	196.6	14.7
0	15.4	19.8	15.1	17.8	14.2	16.0	13.9
5	13.0	115.3	12.8	105.1	12.3	95.6	11.8
5	18.2	12.9	17.4	11.6	16.5	10.8	16.1
6	30.6	13.0	29.8	11.8	28.6	11.0	27.5
0	9.4	37.0	9.2	35.0	9.0	35.9	9.6
4	5.4	13.0	5.0	11.2	4.5	10.1	4.1

312-11 and Supplement to Employment and Earnings September 1980

Not only has Massachusetts made significant gains in total employment in the five year period, but it has held its share of United States factory employment and substantially increased participation in the high-technology component as shown below.

in 000's

Year	United States		Massachusetts			
	Manuf.	Hi-Tech	Manufacturing		Hi-Technology	
			No.	% U.S.	No.	% U.S.
1975	18,323.0	2,748.0	577.6	3.2	167.6	6.1
1976	18,997.0	2,855.0	595.2	3.1	172.8	6.1
1977	19,682.0	3,007.6	618.3	3.1	190.8	6.3
1978	20,505.0	3,232.0	652.9	3.2	206.4	6.4
1979	21,062.0	3,433.0	671.7	3.2	222.0	6.5

This was achieved despite the slide in textiles, apparel, and leather and the stable levels in other non-high-technology manufacturing categories.

Massachusetts compares most favorably with the other large industrial states in the gain in its share of United States high-technology employment. As shown below only California, Texas and Florida reported a greater proportion of U.S. high technology employment in 1979 than in 1975. All other states either fell short of the 1975 percent or remained unchanged.

10 Largest	Percent of U.S. High Technology Employment				
INDUSTRIAL STATES	1979	1978	1977	1976	1975
MASSACHUSETTS	6.5	6.4	6.3	6.1	6.1
California.	16.7	16.2	15.4	15.4	15.3
Florida	2.9	2.7	2.4	2.2	2.2
Illinois.	7.1	7.5	7.8	7.8	8.4
Michigan.	2.7	2.8	2.7	2.7	2.7
New Jersey.	5.3	5.5	5.8	5.9	6.1
New York.	10.9	11.2	11.0	12.4	12.5
Ohio.	4.7	5.2	5.5	5.3	5.4
Pennsylvania.	6.1	6.5	6.6	7.0	7.2
Texas	4.2	3.9	3.8	3.7	3.5

In 1979, Massachusetts stands in first place among these states in the proportion that high-technology is of manufacturing, but with a smaller population and fewer nonfarm jobs than any of these same states rank fourth in terms of total employment in high-technology industries.

EMPLOYMENT 1979

In Thousands

STATE	Total Employment	High Tech Employment Number	Percent of Manuf.	Rank
MASSACHUSETTS	2,543.8	222.0	33.0	1
California	9,894.3	574.9	28.7	2
Florida	3,399.6	98.3	22.2	5
Illinois	4,732.3	242.5	18.9	6
Michigan	3,499.5	92.3	8.0	10
New Jersey	2,975.0	182.2	23.0	4
New York	7,101.1	375.0	25.0	3
Ohio	4,227.5	161.9	11.7	9
Pennsylvania	4,519.4	209.9	15.1	7
Texas	5,496.4	143.6	14.1	8

Annual Average Wages in High Technology Industries

Average annual wages in high-technology industries in Massachusetts, estimated at $16,270, are almost 30 percent above the average for all subject employment and some 10 percent higher than manufacturing.

Because of the differences in the industrial structure of the states in the survey, wage comparisons of the "all subject" employment and "manufacturing" employment categories do not appear to be valid. The high-technology components are however much more homogenous. In this group the average annual wage in Massachusetts at $16,270 in 1979 ranks below Michigan $18,970, New York $18,870, California $17,390, New Jersey $17,220. All except California are northern or eastern states.

Compilations of Employment and Wage Data

Submitted by Cooperating States

The tables on the following pages include all the employment data submitted by the states that cooperated in this survey.

Broadly the tables provide comparisons of employment and annual average wages for each of the categories-- total employment, manufacturing employment and employment in high-technology industries for each state for the years 1975-1979. Included in the tables are percent changes to 1979 from the base year 1975 and the percent that each sub group is of the whole. The rank of each state in 1979 in each category is also shown. Only employment data for the United States has been included.

These compilations have been included to provide data for further review and analysis of development in high-technology employment.

TABLE 1 TOTAL[1], MANUFACTURING, AND HIGH TECHNOLOGY EMPLOYMENT AND RANK
PERCENT CHANGE FROM 1975 TO 1979
UNITED STATES AND SELECTED STATES
(EMPLOYMENT IN THOUSANDS)

STATE	ALL SUBJECT EMPLOYMENT			MANUFACTURING EMPLOYMENT			HI-TECHNOLOGY EMPLOYMENT		
	NUMBER	PERCENT CHANGE FROM '75	RANK	NUMBER	PERCENT CHANGE FROM '75	RANK	NUMBER	PERCENT CHANGE FROM '75	RANK
UNITED STATES *	89,886.0	14.4	-	21,062.0		-	3,433.0	24.9	-
Arizona	954.2	60.7	2	144.7	46.0	2	57.8	41.4	11
California	9,894.3	43.7	6	2,006.2	26.6	9	574.9	36.7	13
Connecticut	1,390.0	16.3	24	436.2	11.8	18	94.4	18.0	19
Colorado	1,203.6	49.8	3	180.9	33.2	4	53.1	61.0	7
Florida	3,399.6	27.4	16	442.6	30.8	5	98.3	61.4	6
Georgia	2,085.4	42.0	8	529.7	21.0	13	1.4	34.0	14
Illinois	4,732.3	25.1	18	1,284.2	6.1	22	242.5	5.4	25
Maine	391.4	38.7	10	114.7	19.2	14	10.6	71.8	4
Maryland	1,681.6	39.0	12	248.4	7.7	21	37.3	27.0	16
MASSACHUSETTS	2,543.8	35.6	13	671.7	16.3	17	222.0	32.4	15
Michigan	3,499.5	20.7	22	1,163.0	21.5	12	92.3	26.0	17
Minnesota	1,708.5	21.1	20	380.8	22.2	11	104.8	38.2	12
Nevada	381.3	71.9	1	19.4	59.6	1	3.6	104.3	1
New Hampshire	374.4	44.1	5	116.5	36.2	3	36.5	78.4	3
New Jersey	2,975.0	30.8	14	792.0	5.5	23	182.2	9.1	22
New York	7,101.1	21.7	19	1,500.4	5.1	24	375.0	9.6	21
North Carolina	2,317.4	38.0	11	824.2	17.9	15	83.7	52.2	8
Ohio	4,227.5	14.3	25	1,379.0	8.9	20	161.9	8.8	23
Pennsylvania	4,519.4	20.9	21	1,392.4	3.9	25	209.9	6.8	24
Rhode Island	399.6	25.3	17	134.7	17.1	16	19.2	19.6	18
Texas	5,496.4	42.7	7	1,019.0	25.6	10	143.6	50.2	9
Utah	482.2	29.9	15	86.3	28.9	6	17.9	66.0	5
Vermont	190.8	41.1	9	50.9	28.5	7	15.9	45.2	10
Virginia	1,568.1	20.5	23	412.7	10.6	19	40.1	11.8	20
Washington	1,569.8	48.4	4	309.0	27.0	8	19.3	90.9	2

1 Employment in establishments subject to state employment security laws.
* Source: Employment and Earnings, U.S. -1909-1978 Bulletin No. 1312-11 and Supplement to Employment and Earnings September 1980

TABLE 2 TOTAL EMPLOYMENT
UNITED STATES AND SELECTED STATES
1975 - 1979
(Employment in Thousands)

STATES	1979		1978	1977	1976	1975
	Employment	Rank	Employment	Employment	Employment	Employment
UNITED STATES *	89,886.0	-	86,697.0	82,471.0	79,382.0	76,945.0
Arizona	954.2	19	871.2	672.0	621.5	593.8
California	9,894.3	1	9,358.0	7,859.0	7,447.1	6,887.3
Connecticut	1,390.0	17	1,335.0	1,262.6	1,216.0	1,195.5
Colorado	1,203.6	18	1,120.9	912.8	858.7	803.7
Florida	3,399.6	8	3,208.3	2,838.7	2,676.8	2,668.2
Georgia	2,085.4	12	2,011.0	1,619.2	1,542.1	1,468.5
Illinois	4,732.3	4	4,617.1	3,924.8	3,819.8	3,781.8
Maine	391.4	22	379.5	309.4	299.8	282.1
Maryland	1,681.6	14	1,631.1	1,308.8	1,264.1	1,210.0
MASSACHUSETTS	2,543.8	10	2,460.4	2,060.8	2,004.0	1,975.7
Michigan	3,499.5	7	3,456.0	3,217.8	3,054.5	2,900.2
Minnesota	1,708.5	13	1,629.2	1,530.5	1,455.8	1,410.6
Nevada	381.3	23	347.4	269.4	237.8	221.9
New Hampshire	318.8	24	299.1	276.9	257.2	238.2
New Jersey	2,975.0	9	2,876.0	2,379.1	2,321.0	2,275.1
New York	7,101.1	2	6,917.7	5,918.2	5,842.0	5,834.1
North Carolina	2,317.4	11	2,154.2	1,849.4	1,777.0	1,679.2
Ohio	4,227.5	6	4,133.3	3,899.0	3,768.0	3,698.5
Pennsylvania	4,519.4	5	4,409.5	3,878.1	3,796.4	3,739.1
Rhode Island	399.6	21	393.4	350.9	336.1	318.1
Texas	5,496.4	3	5,185.6	4,289.3	4,064.9	3,851.4
Utah	482.2	20	459.5	384.5	361.0	371.3
Vermont	190.8	25	183.5	146.7	140.7	135.3
Virginia	1,568.1	16	1,514.2	1,425.0	1,359.0	1,301.1
Washington	1,569.8	15	1,326.2	1,194.1	1,067.7	1,058.0

* Source: Employment and Earnings, U.S.-1909-1978 Bulletin No. 1312-11 and Supplement to Employment and Earnings September 1980

D AS A PERCENT OF TOTAL EMPLOYMENT
AND SELECTED STATES
5 - 1979
t In Thousands)

	1977		1976		1975	
Per. Subj. Emp.	Manufact-uring	Per. Subj. Emp.	Manufact-uring	Per. Subj. Emp.	Manufact-uring	Per. Subj. Emp.
23.7	19,682.0	23.8	18,997.0	23.9	18,323.0	23.8
14.7	114.7	17.1	104.1	16.8	99.1	16.7
20.1	1,730.3	22.0	1,650.2	22.2	1,584.8	23.0
31.4	406.8	32.2	397.1	32.7	390.1	32.6
14.9	152.7	16.7	142.4	16.6	135.8	16.9
13.0	377.3	13.3	345.4	12.9	338.3	12.7
25.7	496.0	30.6	476.0	30.8	438.0	29.8
27.4	1,228.3	31.3	1,190.9	31.2	1,210.6	32.0
29.3	106.1	34.3	102.6	34.2	96.3	34.1
14.8	233.2	17.8	230.9	18.3	230.7	19.1
26.5	618.3	30.0	595.2	29.7	577.6	29.2
34.0	1,121.2	34.8	1,052.9	34.5	957.3	33.0
22.1	339.5	22.2	320.6	22.0	311.6	22.1
5.1	15.1	5.6	13.0	5.5	12.2	5.5
36.7	101.4	36.7	94.4	36.7	85.5	35.9
27.3	768.3	32.3	759.2	32.4	751.1	33.0
21.5	1,461.9	24.7	1,443.9	24.7	1,427.2	24.5
37.4	779.5	42.1	754.5	42.5	699.2	41.6
33.4	1,341.7	34.4	1,293.6	34.3	1,266.7	34.2
31.1	1,349.7	34.8	1,339.3	35.3	1,340.7	35.9
34.6	131.1	37.4	125.5	37.3	115.0	36.1
18.5	901.7	21.0	855.9	21.1	811.5	21.1
17.3	73.9	19.2	70.0	19.4	67.0	18.0
26.0	43.4	29.6	41.1	29.2	39.6	29.3
27.3	402.1	28.2	388.3	28.6	373.2	28.7
21.5	260.2	21.8	247.3	23.2	244.0	23.1

nd Supplement to Employment and Earnings September 1980

Y INDUSTRIES AND AS A PERCENT OF MANUFACTURING EMPLOYMENT
D STATES AND SELECTED STATES

1975 - 1979

Employment in thousands)

1978		1977		1976		1975	
-Tech).	Per. Mfg. Emp.	Hi-Tech Emp.	Per. Mfg. Emp.	Hi-Tech Emp.	Per. Mfg. Emp.	Hi-Tech Emp.	Per. Mfg. Emp.
232.0	15.8	3,007.6	15.3	2,855.0	15.0	2,748.0	15.0
47.8	37.7	43.1	37.6	40.9	39.3	3,726.4	37.6
524.1	28.0	464.2	26.8	439.2	26.6	420.6	26.5
91.7	21.9	86.2	21.2	83.3	21.0	80.0	20.5
44.2	26.4	40.0	26.2	36.2	25.4	33.0	24.3
86.3	20.7	72.6	19.2	63.2	18.3	60.9	18.0
1.3	0.3	1.2	0.2	1.1	0.2	1.1	0.2
241.3	19.1	235.4	19.2	225.7	19.0	229.9	19.0
8.9	8.0	7.5	7.1	6.8	6.7	6.1	6.4
33.4	13.8	30.6	13.1	30.6	13.2	29.4	12.7
206.4	31.6	190.8	30.9	172.8	29.0	167.6	29.0
91.4	8.0	79.8	7.1	74.9	7.1	73.3	7.7
97.2	27.0	88.6	26.1	81.0	25.3	75.8	24.3
3.2	18.0	2.4	15.8	2.0	15.5	1.8	14.5
32.3	29.4	28.5	28.1	24.5	26.0	20.4	23.9
77.3	22.5	173.4	22.6	167.2	22.0	167.0	22.2
60.9	24.2	345.3	23.6	343.4	23.7	342.3	24.0
74.7	9.3	68.1	8.7	59.7	7.9	55.0	7.9
68.0	12.2	164.9	12.3	151.1	11.7	148.9	11.8
09.0	15.2	197.5	14.6	199.9	14.9	196.6	14.7
21.0	15.4	19.8	15.1	17.8	14.2	16.0	13.9
24.5	13.0	115.3	12.8	105.1	12.3	95.6	11.8
14.5	18.2	12.9	17.4	11.6	16.5	10.8	16.1
14.6	30.6	13.0	29.8	11.8	28.6	11.0	27.5
39.0	9.4	37.0	9.2	35.0	9.0	35.9	9.6
15.4	5.4	13.0	5.0	11.2	4.5	10.1	4.1

. 1312-11 and Supplement to Employment and Earnings September 1980

TABLE 5 HIGH TECHNOLOGY EMPLOYMENT AS A PERCENT OF TOTAL EMPLOYMENT
UNITED STATES AND SELECTED STATES
1975 - 1979

	1979					
	PERCENT	Rank	1978	1977	1976	1975
UNITED STATES *	3.8	-	3.7	3.6	3.6	3.6
Arizona	6.1	5	5.5	6.4	6.6	6.3
California	5.8	8	5.6	5.9	5.9	6.1
Connecticut	6.8	4	6.9	6.8	6.9	6.7
Colorado	4.4	13	3.9	4.4	4.2	4.1
Florida	2.9	17	2.7	2.6	2.4	2.3
Georgia	0.1	25	0.1	0.1	0.1	0.1
Illinois	5.1	10	5.2	6.0	6.0	6.1
Maine	2.7	18	2.4	2.4	2.3	2.2
Maryland	2.2	22	2.0	2.3	2.4	2.4
MASSACHUSETTS	8.7	2	8.4	9.3	8.6	8.5
Michigan	2.6	19	2.6	2.5	2.5	2.5
Minnesota	6.1	6	6.0	5.8	5.6	5.4
Nevada	1.0	24	1.0	1.0	1.0	1.0
New Hampshire	11.4	1	10.8	10.3	9.5	8.6
New Jersey	6.1	7	6.2	7.3	7.2	7.3
New York	5.3	9	5.2	5.8	5.9	5.9
North Carolina	3.6	16	3.5	3.7	3.4	3.3
Ohio	3.8	14	4.1	4.2	4.0	4.0
Pennsylvania	4.6	12	4.7	5.1	5.3	5.3
Rhode Island	4.8	11	5.3	5.7	5.3	5.0
Texas	2.6	20	2.4	2.7	2.6	2.5
Utah	3.7	15	3.2	3.3	3.2	2.9
Vermont	8.3	3	8.0	8.8	8.4	8.1
Virginia	2.6	21	2.6	2.6	2.6	2.8
Washington	1.2	23	1.2	1.1	1.0	1.0

* Source: Employment and Earnings, U.S.-1909-1978 Bulletin No. 1312-11 and Supplement to Employment and Earnings September 1980

TABLE 6 ANNUAL AVERAGE WAGES IN TOTAL EMPLOYMENT[1].

SELECTED STATES

1975 - 1979

STATE	Average Wage	Rank	1978 Annual Average Wage	1977 Annual Average Wage	1976 Annual Average Wage	1975 Annual Average Wage
UNITED STATES	INA	-	INA	INA	INA	INA
Arizona	$ 12,330	16	$ 11,190	$ 10,520	$ 9,870	$ 9,380
California	14,000	5	12,900	12,000	11,200	10,680
Connecticut	13,580	9	12,500	11,700	11,040	10,450
Colorado	12,950	11	8,950	11,200	10,540	9,800
Florida	11,500	19	10,560	10,180	9.650	9,050
Georgia	11,800	18	10,920	10,440	9,770	9,080
Illinois	14,030	4	12,970	11,980	11,180	10,600
Maine	10,360	25	9,560	9,040	8,620	7,900
Maryland	12,470	15	11,820	11,310	10,900	8,860
MASSACHUSETTS	12,660	14	11,750	11,000	10,340	9,730
Michigan	15,750	1	14,630	13,560	12,530	11,430
Minnesota	12,850	13	11,820	10,920	10,330	9,600
Nevada	12,880	12	12,060	11,180	10,500	9,870
New Hampshire	11,100	22	10,170	9,340	8,790	8,230
New Jersey	13,950	7	12,850	12,300	11,570	10,860
New York	14,330	3	13,400	12,620	11,920	11,250
North Carolina	10,970	23	10,240	9,400	8,870	8,300
Ohio	13,860	8	12,850	12,070	11,220	10,280
Pennsylvania	14,000	6	12,100	11,460	10,740	10,030
Rhode Island	11,430	21	10,500	9,700	9,280	8,780
Texas	13,080	10	11,910	11,120	10,300	9,470
Utah	11,980	17	10,900	10,250	9,500	8,630
Vermont	10,890	24	10,090	9,450	8,930	8,380
Virginia	11,450	20	10,710	10,010	9,400	8,740
Washington	14,360	2	14,330	12,110	12,020	10,760

1. Subject to State Employment Security Laws

TABLE 7 ANNUAL AVERAGE WAGES IN MANUFACTURING EMPLOYMENT

SELECTED STATES

1975 - 1979

STATE	1979 Average Annual Wage	Rank	1978 Average Annual Wage	1977 Average Annual Wage	1976 Average Annual Wage	1975 Average Annual Wage
UNITED STATES	INA		INA	INA	INA	INA
Arizona	$ 15,470	13	$ 14,020	$ 13,130	$ 12,290	$ 11,610
California	16,290	8	14,970	14,130	13,240	12,460
Connecticut	16,820	5	15,350	14,260	13,310	12,470
Colorado	16,080	10	14,830	13,870	12,840	11,970
Florida	13,380	19	12,230	11,430	10,790	10,140
Georgia	12,250	23	11,250	10,460	9,720	8,830
Illinois	16,900	4	15,420	13,790	12,890	12,310
Maine	12,180	24	11,110	10,270	9,500	8,670
Maryland	15,830	12	15,000	13,810	12,780	11,750
MASSACHUSETTS	14,780	15	13,600	12,690	11,820	11,100
Michigan	20,920	1	19,470	18,190	16,570	14,800
Minnesota	16,040	11	14,820	13,720	12,890	11,810
Nevada	14,750	16	13,460	12,530	11,680	11,090
New Hampshire	12,850	21	11,660	10,810	10,060	9,420
New Jersey	16,370	7	15,110	14,120	13,160	12,330
New York	16,740	6	15,440	14,370	13,410	12,540
North Carolina	11,570	25	10,550	9,710	8,990	8,190
Ohio	18,040	3	16,600	15,350	14,040	12,710
Pennsylvania	16,090	9	14,690	13,590	12,540	11,630
Rhode Island	12,280	22	11,140	10,430	9,950	9,380
Texas	15,440	14	14,040	12,950	11,990	11,060
Utah	13,960	17	12,880	11,910	11,010	10,210
Vermont	13,870	18	12,730	11,760	11,090	10,280
Virginia	12,910	20	11,990	11,080	10,240	9,420
Washington	18,600	2	16,890	15,590	14,560	13,410

TABLE 8 ANNUAL AVERAGE WAGES IN HIGH TECHNOLOGY EMPLOYMENT

SELECTED STATES

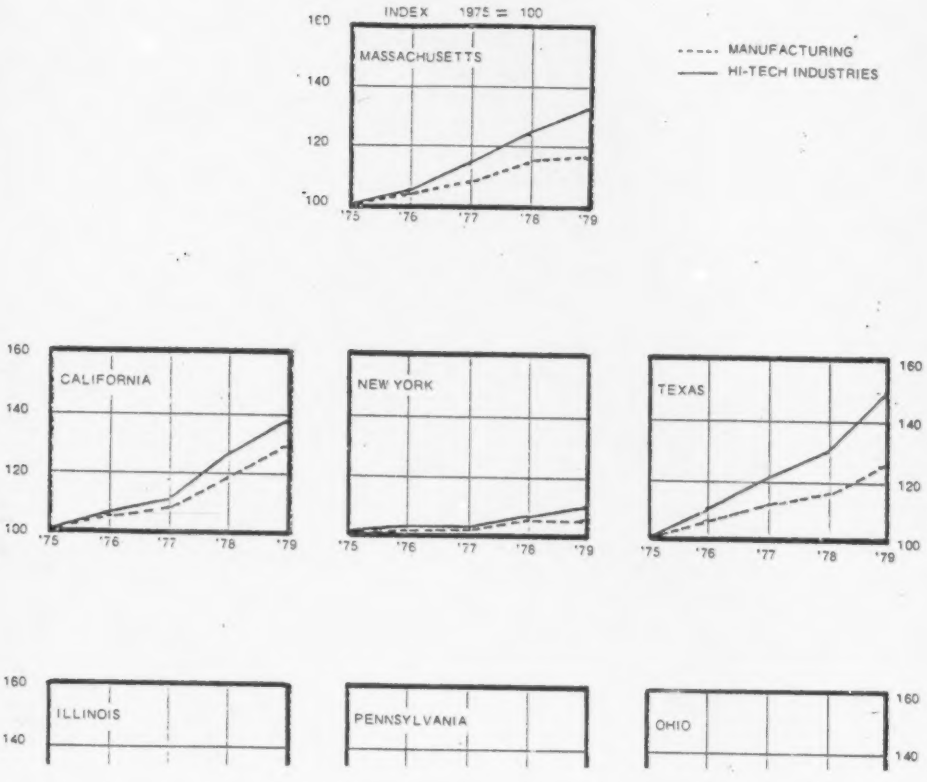
1975 - 1979

STATE	1979 Average Annual Wage	Rank	1978 Average Annual Wage	1977 Average Annual Wage	1976 Average Annual Wage	1975 Average Annual Wage
UNITED STATES	NA		NA	NA	NA	NA
Arizona	$17,440	4	$15,450	$14,380	$14,040	$13,024
California	17,390	5	16,030	15,340	14,450	13,720
Connecticut	16,510	10	15,100	14,000	13,080	12,330
Colorado	17,780	3	17,200	15,350	14,200	13,660
Florida	15,250	14	14,080	13,230	12,560	11,920
Georgia	13,140	21	12,320	11,000	10,510	9,950
Illinois	14,790	17	14,020	12,560	11,740	11,160
Maine	11,420	25	10,590	9,980	9,320	8,570
Maryland	16,650	9	16,630	15,220	14,380	13,740
MASSACHUSETTS	16,270	12	15,010	14,100	13,220	12,450
Michigan	18,970	1	17,530	15,500	14,320	13,200
Minnesota	16,600	8	15,160	14,500	13,630	12,660
Nevada	12,830	23	11,360	10,670	10,310	9,400
New Hampshire	13,060	22	12,300	11,430	10,840	10,400
New Jersey	17,220	6	16,640	15,240	14,420	15,160
New York	18,870	2	17,450	16,330	15,180	14,240
North Carolina	14,670	20	13,230	12,180	11,340	10,820
Ohio	15,760	13	14,780	13,630	12,690	11,650
Pennsylvania	16,470	11	15,320	14,740	13,170	12,340
Rhode Island	14,770	18	12,530	11,810	11,580	10,830
Texas	15,100	15	13,220	12,550	11,530	10,710
Utah	12,230	24	11,320	10,360	9,880	9,430
Vermont	17,180	7	15,720	14,750	14,090	12,860
Virginia	15,070	16	13,960	13,120	12,190	11,160
Washington	14,730	19	13,550	12,860	12,050	11,340

INDEXES OF MANUFACTURING AND HIGH TECHNOLOGY EMPLOYMENT

TEN LARGEST INDUSTRIAL STATES

1975 - 1979



Manpower Strategies For New England's High Technology Sector

Peter B. Doeringer
Boston University

Patricia Pannell
Bentley College

Prepared for the Conference on Manpower Policy Issues, sponsored by the Commission on Higher Education and the Economy of New England, at the Harvard University Graduate School of Business Administration, May 15, 1981.

MANPOWER STRATEGIES FOR NEW ENGLAND'S HIGH TECHNOLOGY SECTOR

Peter B. Doeringer, Boston University
Patricia M. Pannell, Bentley College

"High technology" industry has come to symbolize growth and modernity in the New England economy of the 1980's. This industry has a public image of extraordinary prosperity; of involvement with the advanced technologies of computers, aerospace, optics, and scientific research; and of an insatiable appetite for scientific and technical personnel. This image has been reinforced by media coverage; by the aggressive political advocacy of business groups such as the Massachusetts High Technology Council; and by the modern facilities of high technology companies that cluster along the region's major highways.

Much of this image of high technology in New England is accurate. There was a dramatic growth spurt during the late 1970's in the high technology sector in New England. Employment rose by approximately one third and included a high proportion of professional and technical personnel. This growth was often coupled with the building of new physical facilities.

There is, however, a hidden side of this industry that constrasts markedly with its conventional image. Often overlooked is the historical record of irregular growth and of employment declines experienced by some high tech industries. The labor market situation of blue collar and clerical workers is often neglected although these groups comprise a far larger proportion of the high tech labor force than do engineers and technicians. Furthermore, as most of the high technology work force is in large companies, little is heard about the small employer; yet small employers constitute about three-quarters of all high technology

businesses.

These features of the high technology sector underscore the need to think in terms of many industries, not one. High technology companies operate in a variety of markets from microprocessors and space age products to household appliances and home movie film. Some firms are large, modern, and growing rapidly; others are small and often marginal. Their technologies vary considerably from the advanced to the traditional. Some firms produce to order; others mass produce their products. There are companies that manufacture final products and there are companies that work on subcontracts from other firms. Some firms operate on the frontiers of defense technology while others are in well-established consumer businesses.

Along with such diversity are found varying degrees of prosperity as markets expand and contract and as the competition from other regions, and from abroad, changes. The conventional image of high growth, high prosperity, and shortages of technical labor applies with greatest force to large computer and electronics companies and to the latter half of the 1970's. In other parts of the high tech sector, and in other time periods, the pattern is less clear-cut.

The diversity of experience within the high technology sector demands a manpower strategy that can be tailored to the many parts of the sector and which can accommodate both growth and decline across a broad range of occupations. To date, the main focus of policy debates has been on meeting labor scarcities, and only in a limited range of

scientific and engineering occupations. Other issues have been neglected. If the record of the past is to be any guide to the future, the concern with expanding the supply of technical manpower is only the beginning of a comprehensive manpower strategy needed for the high technology sector in the 1980's.

In order to fashion such a comprehensive policy, employment trends by industry and occupation are examined in detail below. The employment problems of small and large companies are then contrasted, followed by a concluding section addressing questions of public and private manpower strategies.

I. Employment Trends by Industry

Any definition of the high technology sector must necessarily be arbitrary. Limiting high technology only to the high-visibility computer and electronics companies would, in Massachusetts for example, cover only 13% of manufacturing employment and would exclude many high technology businesses classified in other industries. Broader definitions run the risk of including companies that do not belong in the high technology sector. The compromise adopted in this paper is the definition developed by the Massachusetts Division of Employment Security for analyzing trends in high technology in New England.[1] It includes a wide range of durable goods industries as well as Drugs & Medicines (See Table 1) and covers about one third of manufacturing employment in Massachusetts and about one quarter for New England as a whole.

According to this definition, New England has had high technology

industry since at least the late 1940's. Electrical and nonelectrical machinery, fabricated metal products, and instruments have long been an important part of the region's economic base, particularly in Massachusetts and Connecticut. In the postwar period, these industries have experienced strong growth. Placed in a larger perspective, however, their growth rates have been dwarfed by those in a number of non-manufacturing sectors including services; government; and finance, insurance, and real estate (See Table 2). These non-manufacturing sectors also contributed around six or seven times more to total job growth than did the high technology sector.

The late 1970's was a period of accelerated growth of high technology employment in New England and in particular its rapid spread into the region's northern tier states (See Table 3). Over half of all high technology employment in New England, however, remains concentrated in Massachusetts, giving it more than twice as much high technology employment as second-ranked Connecticut. Because of its share of high technology employment, Massachusetts is representative, in many ways of the high technology sector in New England and its experience is used below to illustrate some specific regional developments.

High technology in Massachusetts increased its share of total employment in the last decade from 6.3 percent to 8.7 percent.[2] The largest percentage gains were in optical instruments, medical instruments, and office and computing machines; industries which accounted for over half of the employment growth during the entire period.

This growth, and the strains it placed on staffing resources, however,

Table 1

HIGH TECHNOLOGY INDUSTRIES

Title	Three-Digit Standard Industrial Classification Code
Drugs & Medicine	283
Ordnance & Accessories, NEC	348
Office Computing & Accounting Machines	357
Electrical & Electronic Machinery, Equipment, & Supplies	
Electric Distributing Equipment	361
Electrical Industrial Apparatus	362
Household Appliances	363
Electric Lighting & Wiring Equipment	364
Radio & TV Receiving Equipment	365
Communication Equipment	366
Electronic Components & Accessories	367
Misc. Electrical Equipment & Supplies	369
Guided Missiles & Space Vehicles & Parts	376
Misc. Transportation Equipment	379
Professional and Photographic Equipment & Watches	
Engineering & Scientific Instruments	381
Measuring & Controlling Devices	382
Optical Instruments & Lenses	383
Medical Instruments & Supplies	384
Opthalmic Goods	385
Photographic Equipment & Supplies	386
Watches, Clocks & Watchcases	387

Source: Massachusetts Division of Employment Security, High Technology Employment in Massachusetts and Selected States, 1975-1979, Boston, MA, March 1981, p. 2.

Table 2

NON-AGRICULTURAL INDUSTRIAL EMPLOYMENT IN NEW ENGLAND
1947-1979

Industry	1947 (000's)	1979 (000's)	Change in Total Number of Jobs (000's)	% Change
Non-agricultural Total	3,332	5,395	2,063	62 %
Manufacturing Total	1,544	1,522	-22	-1
Durable Goods Mfg.	683	924	+241	+35
Lumber & Wood	48	32	-16	-33
Furniture & Fixtures	18	20	+2	+11
Stone, Clay & Glass	21	32	+11	+52
Primary Metals	73	52	-21	-29
Fabricated Metal Products	119	144	+25	+21
Machinery (except electrical)	190	203	+13	+7
Electrical Machinery	112	205	+93	+83
Transportation Equipment	58	138	+80	+138
Instruments	44	98	+54	+123
Nondurable Goods Mfg.	861	598	-263	-31
Food	86	60	-26	-30
Textile Mill Products	280	64	-216	-77
Apparel	87	65	-22	-25
Paper & Allied Products	72	70	-2	-3
Printing & Publishing	55	87	+32	+58
Chemicals & Allied Products	28	42	+14	+50
Rubber Products	59	71	+12	+20
Leather & Leather Products	114	58	-56	-49
Misc. Manufacturing	80	81	+1	+1
Nonmanufacturing Total	1,788	3,873	+2,085	+117
Construction	127	190	+63	+50
Trans. & Public Utilities	228	236	+8	+4
Trade (wholesale & retail)	599	1,160	+561	+94
Finance, Insurance, & Real Estate	129	312	+183	+142
Services & Misc.	368	1,138	+770	+209
Government	337	837	+500	+148

[a] For national data, misc. manufacturing is classified under durable goods manufacturing.

FOURCES: U.S. Dept. of Labor, Bureau of Labor Statistics, "A Generation of Change in the New England Employment Structure, 1947-1979," (Boston: New England Regional Office, 1980), p. 18.

Table 3

HIGH TECHNOLOGY EMPLOYMENT IN THE U.S. AND
IN NEW ENGLAND, 1979

Area	High Technology Employment [a] 1979 (000's)	Percent Change 1975-1979 [b]	High Technology Employment as % of Total Employment	High Technology Employment as % of Mfg. Emp.	Percentage of New England High Technology Employment
United States	3,433	24.9	3.8	16.3	n.a.
New England	399	32.6	7.5	26.1	100.0
Connecticut	94	18.0	6.8	21.6	23.5
Maine	11	71.8	2.7	9.6	2.8
Massachusetts	222	32.4	8.7	33.0	55.6
New Hampshire	37	78.4	11.4	31.6	9.3
Rhode Island	19	19.6	4.8	14.1	4.8
Vermont	16	45.2	8.3	31.4	4.0

[a] Employment in establishments subject to state employment security laws.

[b] Increase 1975-1979 reflects extension of coverage to state and local governments in 1978.

Source: Compiled from Massachusetts Division of Employment Security, High Technology Employment in Massachusetts and Selected States, 1975-1979, March 1981, pp. 9-12.

did not occur uniformly throughout the sector. In fact, electrical distributing equipment, watches and clocks, radio and TV receiving equipment actually lost employment (See Table 4). Because of variations in the location of industry and in the prosperity of individual firms, growth was also geographically uneven. Certain labor markets such as Marlboro, Lowell, and New Bedford exhibited strong growth during this period, while certain other areas including Fall River, Fitchburg, and Pittsfield actually suffered declines in high technology employment (See Table 5).

Patterns of rapid growth and decline, and of irregular growth by industry and geographical area are not new to the high technology sector. In the early 1950's, for instance, the Massachusetts electronics industry showed very rapid growth, but the 1957-58 recession hit this industry quite sharply.[3] This pattern was repeated in the early 1960's. A number of industries--household appliances, instruments, miscellaneous electrical equipment and so forth--again suffered employment declines between 1960 and 1970 only to rebound during the 1970's. A reverse pattern can be seen in radio and TV equipment and watches and clocks, in which the growth of the 1960's was reversed during the 1970's (See Table 4).

While much of this pattern of growth and decline reflects overall cycles in economic activity, the fortunes of high technology firms are also affected by defense spending. In 1977, for instance, national data show that 80 percent of the employment in the instruments industry was

Table 4

EMPLOYMENT IN THE HIGH TECHNOLOGY INDUSTRIES IN MASSACHUSETTS 1960, 1970, 1980

Standard Industrial Classification (SIC)	Employment			Average Annual Percent Change	
	1960	1970	1980	1960-1970	1970-1980
283	992	1,363	2,619	+3.7%	+9.2%
348[a]	1,824	2,044	5,466	+1.2	+16.7
357	5,252	14,668	45,935	+17.9	+21.3
361	15,992	15,692	5,664	-0.2	-6.4
362	5,912	6,131	5,707	+0.4	-0.7
363	2,361	1,263	1,334	-4.7	+0.6
364	9,133	8,614	8,213	-0.6	-0.5
365	1,455	3,061	2,695	+11.0	-1.2
366	25,886	26,232	32,844	+0.1	+2.5
367	34,311	29,787	49,327	-1.3	+6.6
369	3,791	2,848	5,772	-2.5	+10.3
376	n.a.	n.a.	11,646	n.a.	n.a.
379	24	73	117	+20.4	+6.0
381	2,431	2,610	3,988	+0.7	+5.3
382	7,114	7,750	19,804	+0.9	+15.6
383	962	939	6,175	-0.2	+55.8
384	1,973	1,775	6,352	-1.0	+25.8
385	4,749	6,651	6,037	+4.0	-0.9
386	4,302	10,041	13,311	+13.3	+3.3
387	2,608	2,533	1,276	-0.3	-5.0
Total	131,072	144,075	234,282	+1.0	+6.3

[a] SIC 19, ordnance, was discontinued in 1974 as a separate category and merged with industries in SIC-34, fabricated metal products.

Source: Derived from Massachusetts Division of Employment Security, Employment and Wages State Summaries, 1960, 1970, 1980.

Table 5

TOTAL HIGH TECH EMPLOYMENT IN ELEVEN SELECTED LABOR MARKET AREAS IN MASSACHUSETTS, 1976, 1978

Labor Market Area	High Tech Employment 1976 IV	High Tech Employment 1978 IV	Absolute Growth	% Change	High Tech as % of Total Employment
Boston	122,887	149,234	26,347	+21.4	12.6
Lawrence	15,107	17,336	2,229	14.8	22.3
Marlboro	12,354	17,562	5,208	42.2	51.8
Pittsfield	10,800	10,007	-793	-7.3	22.1
Lowell	7,091	9,702	2,611	36.8	17.0
Springfield	7,617	8,624	1,007	13.2	4.7
Worcester	3,812	4,961	1,149	30.1	3.7
New Bedford	2,516	3,497	981	39.0	6.3
Fitchburg	3,686	3,376	-310	-8.4	9.7
Brockton	2,023	2,496	473	23.4	5.6
Fall River	229	198	-31	-13.5	0.4
Total	188,122	226,993	38,871	20.7	11.9

Source: Robert Vinson and David McKinnon, High Technology Employment Developments Within Selected Labor Market Areas in Massachusetts, Policy and Evaluation Division, Department of Manpower Development, Boston, MA, 1980, p. 4.

defense-oriented as was over half of the employment in both electrical and non-electrical machinery and over 40 percent of that in transportation.[4]

Massachusetts ranked sixth in defense contracts nationally, with approximately three million dollars of prime contracts concentrated in missile and space systems, aircraft engines and related spare parts, and electrical and communications equipment. Connecticut is even more defense-oriented, ranking fourth in the nation.

Prospects for the High Technology Sector in the 1980's

Broad industrial projections show that New England's shift away from manufacturing and into service-producing areas is expected to continue well into the 1980's.[5] The durable goods sector, including high technology firms, is projected to experience below average growth. These projections, however, use data up to the mid-1970's, and thus do not take into account the rapid growth of high technology in the late 1970's. In the absence of more up-to-date projections, what can be said about the prospects for high technology employment in the 1980's?

Optimistic forecasts can be obtained by extrapolating into the 1980's the pattern of the late 1970's when overall growth averaged over 8 percent per year and reached over 20 percent per year in computers. A more pessimistic outlook, however, would be indicated by the data for 1980. While some industries, such as communication equipment and engineering and scientific instruments showed improved growth in 1980, rates of growth in the high technology sector were generally falling, and over half of the twenty high technology industries actually recorded employment declines (See Table 6).[6]

Such a slow-down is consistent with the stop-go history of many high

Table 6

Percentage Change in High Technology Employment, Selected Years

Industry	Percentage Change in Employment 1975-79	Percentage Change in Employment 1979-80
Drugs & Medicine	+10.8	-2.7
Ordnance & Accessories, NEC	+5.6	+8.6
Office Computing & Accounting Machines	+22.4	+16.0
Electrical & Electronic Machinery, Equipment, & Supplies		
Electric Distributing Equipment	-13.6	-2.6
Electrical Industrial Apparatus	+43.9	-8.3
Household Appliances	+3.2	-1.0
Electric Lighting & Wiring Equipment	+3.6	-8.7
Radio & TV Receiving Equipment	-1.2	-7.9
Communication Equipment	+0.8	+11.2
Electronic Components & Accessories	+16.2	+10.9
Misc. Electrical Equipment & Supplies	+26.4	-7.9
Guided Missiles & Space Vehicles & Parts	+2.8	-3.7
Misc. Transportation Equipment	-31.9	+7.3
Professional and Photographic Equipment & Watches		
Engineering & Scientific Instruments	+5.3	+20.6
Measuring & Controlling Devices	+6.9	+10.0
Optical Instruments & Lenses	+11.6	-1.7
Medical Instruments & Supplies	+12.8	-1.8
Opthalmic Goods	+6.6	-14.2
Photographic Equipment & Supplies	+8.6	-12.3
Watches, Clocks & Watchcases	-3.2	-7.7
Total	+8.2	+5.1

Source: Derived from Massachusetts Division of Employment Security, Employment and Wages Summary, 1975, 1979, 1980.

growth industries.

Recognizing that projections in this area are "best-guesses" it seems unlikely that the growth rates of the late 1970's can be sustained since even the fastest growth rates have slackened in 1980. Beyond diminished growth rates, the future of the high technology sector is further clouded by uncertainty over the direction of the U.S. economy generally, and the inherent instability of industries whose fortunes are connected to defense and R & D spending.

With respect to defense, spending has diminished in the last decade relative to other federal expenditures. About one quarter of the federal budget was allocated to defense spending in 1980, in contrast to 40 percent in 1970. The current administration is seeking to reverse this trend, but the extent and timing of this reversal remains highly speculative.

In contrast, recent budget cuts affecting R & D and the sciences, such as those for NASA and the National Science Foundation, will further aggravate the decline, in real terms, that has taken place in the past eight years.[7] This is likely to seriously impede the long-term prospects of industries dependent upon basic research for scientific breakthroughs that can be commercially exploited.

The high technology sector in New England should benefit from increased defense spending. Employment growth linked to such spending, however, can be expected to be uneven and subject to change with political priorities. The projected rise in defense spending will help to offset some of the declines in R & D, although different segments of the high technology sector will be affected by such changes.

II. Implications for Occupational Labor Markets

These trends in overall employment by industry establish a useful set of parameters for understanding the labor market situation in high technology. Fashioning a labor market strategy, however, also requires information on high technology occupations.

Professional & Technical Workers

A recent study of occupational profiles by industry in Massachusetts indicates that eight of the twenty high technology industries have a greater-than-average share of their employment in professional and technical occupations. Overall, 29 percent of the workforce in these eight high technology industries were professional and technical workers, ranging from a high of 37.8 percent in optical instruments and lenses to a low of 21.9 percent in electronic components and accessories (See Table 7). If growth occurs in these industries, it will place a disproportionate strain on professional and technical labor markets.

While the future demand for professional and technical workers in the high technology sector is uncertain, more general labor market projections for the 1980's show a continued growth in demand for professional, managerial, technical, and other white collar workers. Several fast-growing non-high technology industries, such as medical services and legal services are expected to be competing for these highly educated workers (See Table 7). Within the overall professional and technical category, however, specific occupations show distinctly different patterns of labor market imbalances.[8] The following examples illustrate this point.

Table 7

INDUSTRY[1] GROUPS IN WHICH 20 PERCENT OR MORE OF THE WORKERS ARE EMPLOYED IN PROFESSIONAL OR TECHNICAL ACTIVITIES, 1976

SIC Code	Industry Title	Employment [a] All	Employment [a] Prof. or Technical	Percent Prof. or Technical
	ALL INDUSTRIES	2,299,200	428,000	18.6 %
	SELECTED DURABLE GOODS INDUSTRIES			
192	Ammunition (exc. small arms)	11,500	3,300	28.6
194	Sighting & Fire Control Equip	3,500	1,900	55.2
343	Plumbing & Heating Products except Electrical	1,200	400	31.9
357	Office, Computing & Acc. Mach.	23,100	8,200	35.6
361	Elect. Trans. & Dist. Equip.	19,300	5,000	26.0
366	Communications Equip.	22,000	5,200	23.4
367	Electronic Comp. & Accessories	30,300	6,600	21.8
381	Engineering & Sci. Inst.	1,900	600	30.1
382	Instr. for Measuring, Controlling	9,600	2,800	28.9
383	Optical Instr. & Lenses	4,700	1,800	37.8
386	Photo. Equip. & Supplies	12,100	3,100	26.0
	SELECTED NONMANUFACTURING INDUSTRIES			
80	Medical & Other Health Serv.	203,200	90,500	44.5
81	Legal Services	10,500	3,600	34.6
82	Educational Services	220,500	128,600	58.3
84	Museums & Art Galleries	2,200	500	23.8
86	Nonprofit Membership Organizations	48,100	16,800	34.2
89	Misc. Services[b]	32,600	19,500	59.7
91	Federal Government	57,800	12,900	22.3

[a] 1976 Wage & Salary Employment (excludes self-employed).

[b] Engineering & Architectural Services; Nonprofit Educational & Research Agencies; Accounting, Auditing & Bookkeeping Services; other N.E.C.

Source: Charlotte Meisner and Susan Rico, Massachusetts Division of Employment Security, Occupational Industrial Research Division, An Occupational Profile of the Employed Worker, 1976, March 1980, p. 3.

Engineers. Historically, the supply of college-trained engineers has fluctuated widely as students adjust to changing labor market conditions. For instance, the number of engineering degrees conferred during the 1960's rose by one third in response to high demand in the late 1950's and early 1960's. In contrast, the number of engineering degrees actually fell in the 1970's under the influence of deteriorating employment conditions in the late 1960's and early 1970's. Just as enrollments were declining, however, the demand for engineers rebounded. The net result is today's shortage of engineers.

Although declining college enrollments are anticipated throughout the 1980's, engineering programs are again expanding as students respond to the improved job and salary conditions. In fact, the supply of engineering degrees conferred annually is projected to rise almost 50 percent by 1985.[9] Shortages are expected to shrink, but will still be felt into the mid-1980's if employment needs continue to expand. There is no precedent, however, for expecting that engineering enrollments will fail to catch up with demand as long as pay and advancement opportunities continue to be good.

Computer Specialists. The market for computer specialists has been strong throughout the 1960's and 1970's and employment is expected to continue to grow well above average during the 1980's. Unlike the fluctuations in the supply of new engineers, the number of new computer and informations systems specialists has been steadily climbing in the past two decades. Despite this steady increase in supply, the total number of computer specialists continues to fall short of labor market needs.

These labor market shortfalls are disappearing more rapidly in those computer jobs requiring relatively less skill, while adjustments in the top-skilled areas are taking longer to complete. For example, the market for keypunchers and console operators is already becoming saturated, while the labor market for computer programmers is not expected to come into balance until the mid-1980's. The demand for systems analysts still far surpasses the supply of qualified workers, and if current trends continue, it is expected that these needs will remain unmet in the mid-1980's.

Blue Collar Workers

Crude data on the occupational composition of the high technology sector shows that about one half to two thirds of all employees perform production and maintenance work.[10] In some parts of the high technology sector, such work may require substantial skill--the ability to weld exotic metals to very precise specifications, toolmaking and machine tool set-up, and testing and quality control. In mass production operations, however, the bulk of the production work is routine. Thus, while the numbers employed in these operations are substantial, motivation and attitude are often more important traits than particular skills which can be learned on the job.

Spot shortages of production and maintenance workers, however, may occur from time to time. For instance, companies that are growing rapidly, or which are not competitive in terms of pay, may experience recruitment problems or high turnover among skilled workers. Scarcities may also

occur in companies operating night shifts.

General demographic trends may also contribute to future staffing problems. For instance, the declining proportion of youth in the labor force will contract the pool from which the high technology sector heavily draws production workers.[11] Moreover, some companies, particularly those employing machine tool production technologies, may face high replacement needs because of the disproportionate number of older workers in machining occupations.[12] This is a less critical factor in the case of machine tool operators who usually hold entry-level positions requiring the ability to read blueprints and have some mechanical ability, than for all-around machinists and tool and die makers, positions which generally require several years additional learning on the job.

Clerical Workers

Clerical work accounts for approximately 10 to 15 percent of the jobs in the high technology sector and is, more generally, a growth occupation in all sectors of the New England economy.[13] For example, the employment of secretaries in the region has been growing much faster than the average for all occupations since 1960 and this trend is expected to continue through 1985. The supply of qualified workers for these jobs is not keeping pace with rising demand and a shortage in New England of over 700,000 secretaries is projected for 1985.[14]

Unlike the previously described occupational shortages, part of the secretarial shortage is due to the fact that with the growing array of employment alternatives available to women, many are now passing over

the relatively low-paid, traditionally female jobs which generally lack advancement opportunities. The high technology sector seems to have adapted well to this situation through pay and human resources policies that place it in a strong competitive position with respect to clerical recruitment.

Meeting Manpower Needs

From the preceding discussion, it should be apparent that there are substantial differences among industries in their occupational composition and therefore in the human resource development needs during periods of growth. While blue collar and clerical employment needs are likely to be far more important numerically than those in engineering and scientific classifications, the high technology industry as a whole seems to be able to fill most of its manpower needs in areas other than engineers and technicians with little difficulty. This conclusion is confirmed by data on unfilled vacancies compiled for the Massachusetts High Technology Council.[15] For instance, in 1980 the Council reports vacancy rates for technical professions at 10 percent, with those for electrical/electronic engineers and computer scientists as high as 13 percent. In contrast, vacancy rates for assemblers and production operators were reported to be only 6 percent while clerical vacancies were an unusually low four percent (See Table 8).

One explanation for these different degrees of staffing difficulties in a general growth environment comes from the lags in the education and training system. While the labor market for clerical workers may not be inherently less tight than that for engineers, it simply takes

Table 8

OCCUPATIONAL DISTRIBUTION AND UNFILLED MANPOWER NEEDS OF HIGH TECHNOLOGY COMPANIES,

Occupational Category	Mass. Employment 6/30/80	Percent Unfilled Jobs 8/30/80
Total Technical Professionals	**19,154**	**10**
Electrical/Electronic Engineers	4,948	13
Mechanical Engineers	1,705	7
Computer Specialists	5,355	13
Mathematicians	84	10
Physicists	134	7
Chemists/Chemical	564	7
Other*	6,364	5
Total Technical Paraprofessionals	**11,224**	**6**
Technical-Electronic	3,563	6
Technican-Computer	1,404	6
Technician-Field Service	1,024	8
Computer Programmers	476	11
Drafters	720	10
Printed Circuit Designers	221	10
Other*	3,816	4
Assemblers/Production Operators	**20,803**	**6**
Other Job Categories	**34,481**	**7**
Production	5,405	7
Professionals	10,632	8
Administrative/Clerical	18,444	4
Total Employment	**85,662**	**7**

Source: Coopers and Lybrand, Results of Survey on Human Resource Needs, (Boston, MA: Massachusetts High Technology Council, Inc., January 1981), pp. 8-9.

longer to train additional engineers than additional clerical workers.

A second critical factor is company wage, staffing, and training policies. High paying companies obviously are in a stronger recruitment posture than those that pay below average. Pay also affects skill supplies as educational enrollments by field respond to changes in relative salaries.[16] Like wages, working conditions and growth rates of particular companies can make employment more or less attractive. Finally, firms may engage in skill training and upgrading to alleviate skill shortages and can locate in areas where there is a relatively good supply of labor.

This analysis is confirmed by recent field interviews with high technology companies. High wages, modern facilities, good working conditions, and excellent promotion prospects have characterized many high technology companies. Anecdotal evidence supports the view that production and clerical workers, for example, are relatively better paid than their counterparts in many other industries. This pay margin gives high technology companies the "edge" in both recruitment and retention of these workers.

Among clerical workers and operatives, the suburban location of many high technology companies also allows them to tap expanding suburban labor supplies, particularly women returning to the labor market. Some companies are also finding that location in more rural parts of New England where jobs are relatively scarce, provides similar access to an available blue collar labor pool. Moreover, many of the rapidly growing

firms have relied heavily upon company-sponsored training programs to expand their labor supply by upgrading incumbent employees.

There has not, however, been active use of wage competition as a device for markedly increasing the sector's share of professional and technical workers. This relatively passive pay policy, when combined with rapid growth and training lags, seems to account for many of the recruiting difficulties reported by high technology companies.

III. Contrasting the Human Resource Development Needs of Large and Small Companies

The preceding analysis of high technology employment and occupational imbalances reflects the dominant influence of large companies in the high technology sector. In Massachusetts, for example, one quarter of the firms employ over ninety percent of the workers in the high technology sector. Thus, any overview of the sector and its staffing needs is dominated by the experience of large businesses (See Table 9). Yet small firms (with under 100 employees) deserve attention as both a source of jobs and as the spawning ground for the next generation of industry giants.[17]

The human resource capabilities of large and small firms, and therefore their staffing problems, are distinctly different. In particular, small businesses are far more constrained in their ability to make adjustments to skill shortages than are large firms.[18] Moreover, anecdotal evidence suggests that small businesses may serve as "feeder" firms for larger companies by training workers who then transfer to the larger firms. This labor "swapping" benefits the larger firms, but further

Table 9

HIGH TECHNOLOGY INDUSTRIES IN MASSACHUSETTS
BY FIRM SIZE, 1980

SIC	Number of Firms	Percent of Firms With Less Than 20 Employees	Percent of Firms With Less Than 100 Employees
283	30	63%*	90%*
348	11	n.a.	n.a.
357	118	34	58
361	40	55	90
362	47	51	79
363	23	52	70*
364	70	39	73
365	37	43	73
366	99	42	71
367	307	36	70
369	42	38	71
376	7	0	n.a.*
379	8	50*	50*
381	59	47	83
382	129	47	78
383	57	42	82
384	97	60	86
385	47	62	72*
386	40	58	73
387	11	27*	27*
TOTAL	1,279	44*%	73*%

*These figures represent the lower bound of the number of firms in these categories due to the procedure of reporting statistics to insure employer confidentiality.

Source: MA Division of Employment Security, Occupation/Industry Research, Quarterly Employment and Wage Size Summary for 1980-1.

aggravates the employment problems of small businesses.

Salary Competition

The difficulties in recruiting technical manpower experienced by the high technology sector are compounded for small firms. Small firms often depend upon regional, rather than national, markets for scientific and professional employees so that they face a more limited supply of labor than do large firms. Moreover, pay scales for comparable work are usually lower for small than large firms. Taken together, these factors suggest that wage competition is not likely to be as feasible a device for meeting human resource needs in small high technology companies as it is in larger firms.

Training

Training is the most common alternative to wage adjustments as a human resource strategy. Recent estimates of the amount of formal education taking place in industry today are in the $40-60 billion a year range.[19] Most studies on labor market imbalances and employer training patterns do not report findings by firm size; those that do generally do not include firms with less than 500 employees. One such study, which surveyed over six hundred firms of 500 employees or more, showed that formal education and training activities were far less prevalent in small companies than large. In particular, large companies spent much more money per employee on training ($72 per employee in firms with over 10,000 employees versus $19 in firms employing 500 - 999) and spent a much larger proportion of such expenditures on functional training

than smaller firms.[20] In addition, the likelihood that newly hired employees participated in functional or management training programs increased with firm size. Smaller companies, however, did spend a higher percentage of their limited training budgets on management training.

These findings are generally confirmed in another study although firms were classified only as either greater or fewer than 1000 employees.[21] In the latter survey, smaller employers without formal training programs indicated that they concentrated on recruiting and hiring already-trained employees for their higher skilled jobs; informal on-the-job training was prevalent in many of the lesser-skilled jobs. While there are no estimates on the extent of informal on-the-job training, Department of Labor surveys suggest that on-the-job training is the single most important source of skill development.[22]

Scattered evidence from case studies as well as the recent literature on youth labor markets provides further insight into the hiring and employment practices of various size employers and the mobility of workers between firms of different sizes.[23] In general, smaller firms provide the opportunity for a much more informal and personal employment relationship than is possible in large companies with more formal personnel procedures. In addition, several studies indicate that small businesses try deliberately to stabilize employment by avoiding layoffs whenever possible. Such policies tend to inculcate in workers a sense of loyalty and commitment which contributes to lower rates of employee turnover. Hoarding labor in times of business slowdowns also minimizes the recruiting of new

workers when business picks up.

Small businesses are likely to feel the pinch of industry-wide occupational shortages much more than larger firms. In the face of shortages of higher-skill workers, small firms generally cannot afford to initiate in-house training programs. This lack of formal internal training programs coupled with relatively short job ladders hinders worker mobility and promotion opportunities in small businesses and poses a major problem for them in trying to retain good workers.

IV. Towards a Manpower Strategy

This paper has reviewed the employment trends in New England's high technology sector. It has emphasized that this sector is not monolithic; its employment problems vary by the size and type of firm, location, and rates of growth. A manpower strategy for the high technology sector must, therefore, reflect a variety of key differences within the sectors--technical versus non-technical occupations; growth versus decline; stable versus unstable product markets; and small versus large companies.

A second salient feature of the high technology sector is its uneven pattern of growth. The sector has a history of cycles of alternating growth and retrenchment. Not only do shifts in technology cause irregular growth among firms, but the sector is also affected by shifts in defense and R & D spending and in the inter-regional or international location of production.

Much of the recent policy concern in the industry has been with meeting the employment needs of its growth sector. However, given the "stop-go" employment history of some components of the sector, and recognizing that the sector's term growth prospects have not been well-tested,

it would seem premature to make sweeping changes in the region's education and training system if the payoff from such change depends upon sustained growth. Moreover, it would seem prudent to be alert to the possibility of labor surpluses that often follow rapid growth in an occupation and to balance growth policies with other adjustment policies to cushion the impact of labor dislocation and employment declines.

Balancing the needs of growth against the problems of decline and change requires a sensitivity to distinctions between short-term and long-term labor market conditions. Under the immediate pressure of unfilled jobs, it is tempting to opt for ambitious programs to expand the supply of fully trained workers rather than to rely upon second-best alternatives by which employers adapt to their immediate staffing difficulties. There is ample precedent, however, suggesting that massive programs to build up skill supplies can distort educational priorities and destabilize labor markets in the long term unless they are carefully handled.[24] Some examples of policies for dealing with various labor market problems identified in this paper can serve to illustrate how such a balance might be achieved.

Meeting Engineering and Technical Manpower Needs

The rapid growth in the high technology sector in the late 1970's placed considerable staffing strains on employers. These strains were felt most acutely in engineering and technical occupations because academic enrollments in these fields had been falling off and good substitutes for these skills were not available. During this growth period,

employers experienced substantial shortfalls between desired and actual staffing levels in such occupations.

The tight labor market for engineers caused salaries to rise relative to other types of college-trained manpower and enrollments in engineering programs began to rise. These favorable developments with respect to anticipated increases in the supply of engineers, however, are felt in the labor market only with a considerable lag. The engineering scarcity continues to be perceived as severe although some slackening in the rate of growth in the high technology sector combined with increasing supply suggest that these market stringencies will ease gradually during the 1980's.

The main constraint in this market, nationally, is the lag in career choice decisions by students and in the period of time it takes to educate new engineering personnel. The supply of such skills has been responding to the present scarcity and there do not seem to be any insurmountable bottlenecks in the long-term expansion of the engineering labor force.

The policy issue, therefore, is not whether the scarcity will be reduced, but how fast and at what risk of eventually stimulating surpluses. This implies the need for improved educational planning, greater flexibility in educational programming, and the tapping of non-traditional sources of students who can be retrained for high technology occupations.[25] Only in occupational specialties where the manpower gap is large and where continued demand can be demonstrated should additional incentives be established to accelerate supply increases. These should be monitored

carefully to prevent overproduction of such skills by making sure to account for students already in the pipeline. Over the longer term, this will require changes in how educational capacity, and research capacity, are planned and organized on a regional basis. Such changes, however, are desirable in order to improve the performance of the region's education and training system, independent of the particular problems currently experienced by the high technology sector.

Blue Collar and Clerical Occupations

Because the training times for these occupations are so much shorter than for engineers and technicians, labor scarcities tend to be of shorter duration and to be more readily correctable through a combination of school-based programs and on-the-job training. Moreover, because many parts of the high technology sector have been paying above average salaries, providing good working conditions, and providing a growth environment that encourages employee advancement, the high technology sector can meet its labor needs relatively easily from the local labor market. If there is a labor market scarcity being felt in these occupations in the high technology sector, it is likely to be in terms of quality rather than quantity, except in those high technology companies where pay and working conditions are relatively less favorable.

The greatest impact of labor scarcities in these occupations is likely to occur in sectors other than high technology, that cannot compete as effectively for labor. This is particularly true because high

technology employers often prefer to hire experienced clerical and blue collar workers. Thus, employment policy in local areas should look not only to the needs of the high technology firms but more generally, to other firms who "feed" labor to the high technology sector.

Meeting the Shifting Needs of Industry

Industries such as high technology that are sensitive to shifts in defense contracts and R & D spending pose two sets of problems for human resource development policy. The first problem involves the training for state-of-the-art technologies. By definition, school-based training programs cannot hope to prepare workers for the most advanced skills needed in companies that are at the cutting edge of new technology. The skills required by new technology must be provided first by the scientific and engineering personnel where the technology is first adapted. Workplace training programs must be relied upon to produce such skills.

As products mature, however, there is a somewhat predictable cycle in the level of skill required and in the focus of where the training can be provided.[26] With production experience and increases in the scale of production, it is customary to substitute less highly trained personnel for engineers and scientists. When a technology becomes more generally adopted, it is also possible to formalize the training and instruction in the skills needed so that more of them can be taught in schools.

What is needed is a training policy that parallels this training cycle. Newly emerging skills at the workplace should be transferred to the education and training system as their generality becomes established.

Such transfer requires closer collaboration between schools and innovating firms than is presently the case.

The Special Concerns of Smaller Business

The high technology experience carries special implications for small businesses. As in other areas of management, the small business has relatively few resources to spend on human resource development. Yet human resource management in the small business is a critical factor if the firm is to meet its manpower requirements.

Skill shortages can squeeze the small business at both ends of the occupational hierarchy as larger firms (1) lower their hiring standards to get more workers into their training pipeline and, (2) increase the compensation of top personnel to retain those in high technology development. The small business may thus wish to pay more attention to human resource development within the firm. For instance, small firms could try to internalize the training flows of workers now taking place between firms by reallocating funds used in recruiting high-paid, high-skilled workers from large firms to programs aimed at retaining and upgrading their own semi-skilled employees. Job turnover could be reduced by paying higher salaries to mid-level employees and by establishing internal promotion paths. Not only would the perceived need of lower level workers to move "up and out" be curtailed, but also a considerable degree of employee loyalty would be generated.

Small businesses can also benefit by improving their external relations with human resource development organizations such as the schools and government training programs. This is particularly true given the

increased importance the recruiting function takes on when new employees are looked upon as long-term rather than short-term employees. The small business often encounters difficulties in dealing with schools as it is easier from the school's perspective to maintain a relationship with one large employer than several small employers. Also the desires of small employers for individuals who are more broadly trained, who can take over as a "jack-of-all trades" and handle many facets of the business, pose greater training challenges for schools than would more narrow training.

Small businesses should distinguish different types of schools and their abilities to respond to the particular training needs of small employers. Small businesses regularly overlook the proprietary school, for instance, as a source of labor supply yet, reputable proprietary schools have often been found to precede the public schools in developing programs in areas of new and expanding local labor market demands. Their relatively fast, "no-frills" training approach could well complement the small business work environment.

Dealing With Labor Surpluses

Because the high technology sector's growth pattern has been irregular, because its fortunes are tied to inherently unpredictable markets such as defense, and because it competes both interregionally and internationally, the high technology sector is, over the long-term, likely to experience structural changes that will dislocate labor at all skill levels. This emphasizes the importance of maintaining, even during pros-

perous periods, a placement and retraining capability in local areas to ease the adjustment to dislocation which may be inevitable in such a dynamic industry. The need for such a locally-oriented adjustment process is particularly important for blue collar and clerical employees for whom short-term labor market adjustment problems are likely to be especially severe.

Upgrading the Region's Education and Training System

While the labor market problems of the high technology sector in New England have been the focus of this paper, they illustrate a broader set of policy concerns for the region's education and training system. The education and training needs of the region are currently served by a patchwork of local vocational schools, public and private colleges and universities, proprietary schools, CETA programs, apprenticeship programs, and on-the-job training. Its separate parts are subject to varying pressures--economic, political, and organizational. Its destiny is decentrally controlled and its disparate constituencies make it difficult to subject the system to any common standard of performance.

The system works, but not without sufficient shortcomings to make it ripe for overhaul. During the 1980's many portions of this system will be open to reform. CETA and vocational education legislation both face the scrutiny of congressional reauthorization; public and private higher education institutions are facing the realities of limited financial resources and excess educational capacity; and some employers are becoming increasingly concerned with the system's performance. At a minimum, these pressures create an unusual opportunity for redirecting the planning and program activities in key parts of the education and training system. The experience of the high technology sector underscores the need to prevent immediate labor market concerns from impeding attention to longer-term changes in the region's economic structure.

Footnotes.

1. Massachusetts Division of Employment Security, Job Market Research Division, High Technology Employment: Massachusetts and Selected States, 1975-1979, (Boston, MA: Massachusetts Division of Employment Security, March 1981), p. 2.

2. Ibid., and unpublished statistics from the Massachusetts Division of Employment Security.

3. Neal R. Peirce, The New England States,(New York: W.W. Norton and Company, Inc., 1976); Richard B. Freeman, The Market for College-Trained Manpower, (Cambridge, MA: Harvard University Press, 1971); Everett J. Burtt Jr., The Influence of Labor Supply on Location of Electronics Firms, (Boston, MA: Federal Reserve Bank of Boston, February 1965); and Everett J. Burtt Jr., The Electronics Industry of New England,(Boston, MA: Greater Boston Economic Study Committee, Base Report, No. 10, N.D.).

4. Edward F. Kaznecha et al., Defense Spending and Massachusetts Employment, 1969-1979, (Boston, MA: Job Market Research Division, Massachusetts Division of Employment Security, 1981), pp. 20-22.

5. Gordon E. Bowen, Projections of Industrial Employment in New England to 1985, (Boston, MA: Bureau of Labor Statistics, U.S. Department of Labor, 1977).

6. Massachusetts Division of Employment Security, Occupation/Industry Research Division, Employment and Wages Summary 1980 First, Second, Third and Fourth Quarters, (Boston, MA: Massachusetts Division of Employment Security, 1981).

7. See Peter B. Doeringer, Patricia Pannell, and Pankaj Tandon, "Market Influences on Higher Education: A Perspective for the 1980's," in John C. Hoy and Melvin H. Bernstein, Business and Academia: Partners in New England's Economic Renewal, (Hanover, NH: University Press of New England), forthcoming.

8. For a more detailed analysis of labor market imbalances in the 1980's see ibid.

9. National Center for Educational Statistics, Projections of Educational Statistics to 1986-87, (Washington, DC: U.S. Government Printing Office, 1978), pp. 42-48.

10. Commonwealth of Massachusetts, Executive Office of Economic Affairs, Job Development Resource Guides for the Employment and Training System, Volume II, Occupational Staffing Patterns of Massachusetts Industries, (Boston, MA: Massachusetts Department of Manpower Development, December 1979).

11. See George Masnick's article in this volume. Also, Lynn E. Browne, "A Quality Labor Supply," New England Economic Review, July/August 1981, pp. 19-36.

12. New England Regional Commission, Task Force on Capital and Labor Markets, (Boston, MA: New England Regional Commission, November, 1975), p. 19; Institute on Employment Policy, "Education, Training and Employment in Worcester," (Boston, MA: Institute on Employment Policy, Boston University, 1976).

13. Coopers and Lybrand, Results of Survey on Human Resource Needs, (Boston, MA: Massachusetts High Technology Council, Inc., January 1981), p. 8.

14. T.J. Murray, "The Big Hunt for Secretaries," Dun's Review, (May 1978), pp. 88-90; U.S. Department of Labor, Bureau of Labor Statistics, Occupational Projections and Training Data, (Washington, DC: U.S. Government Printing Office, 1979).

15. Coopers and Lybrand, op cit., pp. 8-9.

16. Richard B. Freeman, op cit.; Walter Fogel and Daniel Mitchell. "Higher Education Decision-Making and the Labor Market," in Margaret Gordon (ed.), Higher Education and the Labor Market, (New York: McGraw-Hill Book Company, 1974), pp. 453-502; Bruce Wilkinson, "Present Values of Lifetime Earnings for Different Occupations," Journal of Political Economy, Vol. 74, (December 1966), pp. 556-572.

17. Stuart W. Bruchey (ed.), Small Business in American Life, (New York: Columbia University Press, 1980); U.S. Senate, Select Committee on Small Business, Small Business and the Quality of American Life, (Washington, DC: U.S. Government Printing Office, 1977); and David L. Birch, The Job Generation Process, (Cambridge, MA: MIT Program on Neighborhood and Community Change, 1979).

18. Patricia Flynn Pannell, "Employer Response to Skill Shortages: Implications for Small Business," Proceedings of the Small Business Research Conference, (Waltham, MA: Bentley College, forthcoming).

19. See Peter Doeringer, (ed.), Workplace Perspectives on Education and Training, (Boston, MA: Martinus Nijhoff Publishing, 1981).

20. Seymour Lusterman, Education in Industry, (New York: The Conference Board, Inc., 1977).

21. Mary G. Miner, Training Programs and Tuition Aid Plans, (Washington, DC: Bureau of National Affairs, Inc., 1978).

22. U.S. Department of Labor, Bureau of Labor Statistics, Occupational Training in Selected Metalworking Industries, (Washington, DC: U.S. Government Printing Office, 1974); U.S. Department of Labor, Bureau of Labor Statistics, Occupational Projections and Training Data, (Washington, DC: U.S. Government Printing Office, 1976). Also see Gerald G. Somers and M. Roomkin, "Developing Reliable Data on Training in Industry," Monthly Labor Review, Vol.___, (February 1974), pp. 33-37; Lewis M. Branscomb and Paul C. Gilmore, Daedalus, (Winter 1975), pp. 222-233.

23. Paul Osterman, Getting Started: The Youth Labor Market, (Cambridge, MA: MIT Press, 1980); Patricia Pannell, op cit.

24. Richard B. Freeman, op cit.; and U.S. Department of Labor, Manpower Report of the President. (Washington, DC: Government Printing Office, 1970 and 1972), 1970, Ch. 7 and 1972, Ch. 5.

A STUDY OF LABOR NEEDS OF THE ELECTRONICS, ENERGY TECHNOLOGY, HEALTH SERVICES, AND METAL FABRICATION INDUSTRIES IN THE GREATER FALL RIVER AREA

Prepared by

The Center for Research and Business Activity
College of Business and Industry
Southeastern Massachusetts University
North Dartmouth, MA 02747

for

Ninth Annual Meeting
New England Business and Economic Association Conference
November 5, 6, 1981

Clyde L. Mitchell
Donald H. James
Ed Parr
William V. Hogan

Introduction

Much attention has been given in recent years to bridging the gap between education/training institutions and the workplace. From these efforts has emerged the perspective that a local economy comprised of government, industry, labor, and education/institutions need to work more closely if a labor supply is to match labor demand.

Out of this scenario arises the concept of an employability development network. This is no new animal on the scene, but a way of viewing what is already in place. Specifically, the Greater Fall River area, a SMSA with a relatively stable population of 146,000 in the southeast corner of the Commonwealth, has an employability development network by virtue of the fact that it is an area which has education opportunities spanning pre-primary through university levels. This concept does not intend to imply that the sole function of education institutions is to supply industry with a labor market. Rather, the concept expresses one responsibility education has toward its students: to equip them with skills and competencies which allow graduates to successfully compete in the job market. Particularly in a SMSA like Fall River, Massachusetts, where little out-migration took place through the 1970's, attention must be given to the local labor demands and the labor demands of potential business/industry entrants into the local economy.

It is this outlook on economic and educational planning that prompted Jobs for Fall River, Inc. to contract the Center for Research and Business Activity of Southeastern Massachusetts University. The study, which this paper highlights, provides an analysis of four industries that are, or are likely to become, significant employers in the Fall River labor market area: electronics and computers, energy, health services, and metal fabrication.

The study also involved a detailed survey of key education/training institutions in the Fall River LMA, with an emphasis on the capacity of these institutions to provide graduates competent to fill the occupational needs of current and potential industries in the area.

Scope and Rationale of the Study

Some 48 firms were interviewed in depth by telephone and/or person-to-person conferences to obtain analytical information on the occupational structures, as well as the current and projected job openings for these firms. Considerable attention was given to the firms under the high technology category for several reasons: 1) these firms have an outstanding growth record in the state, and are continuing a south and southeast expansion from the 128 area where many parent high tech firms are located; 2) these firms are already strong in selected sites, many within reasonable commuting distance from the Fall River LMA, in addition

to the Fall River LMA itself; 3) education and training needs of high tech firms in Massachusetts have and will continue to have a direct impact on the success of education/training networks from the perspective of employability development. Localities which offer educational programs compatible with industry needs are more likely relocation areas.

Energy technology was considered in this study primarily due to E.G. & G.'s proposed coal gasification plant currently in final stages of a detailed feasibility study. Understanding and preparing to provide for the labor needs of this 1,000 person workforce would assure increased employment for the Fall River Labor Market.

In Fall River, because of the moderately large proportion of senior citizens, the health care industry will continue to have substantial workforce demands. Facing the same crucial shortages as other health care labor markets and the increasing complexity and change in health care technology, education institutions supplying the industry need to keep current in this industry's labor needs.

Finally, metalworking firms, suppliers to many high technology firms, continue to have both replacement and moderate expansion demand for skilled labor.

The study provided a detailed description of the occupational needs of each industry to facilitate educational planning and collaboration among the five key institutions serving the Fall River area. What follows is a summary of the labor needs for each industrial cluster.

High Technology Labor Needs

Survey responses were obtained from 30 high technology firms in southeastern and eastern Massachusetts. Although no two high technology firms are exactly alike in their occupational structures, a number of similarities were found. Of the firms interviewed, each attached importance to the following broad occupational fields: (1) Management, (2) Engineering, (3) Computer Science, (4) Electronic Technicians, (5) Computer Programmers, (6) Electronic Drafters, (7) Technical Writers, (8) Administrative and Secretarial Personnel, and (9) Assemblers and other Production Workers.

High technology firms have a tendency to include managerial and professional personnel into a single category. A number of persons in upper management are often drawn from the ranks of the engineers, scientists, and related professionals. In such cases, a continuing education program is recommended, most often leading to an MBA. Persons hired into management from outside a firm usually need an MBA with prior experience. In most managerial and professional categories, inter-company recruitment as well as reliance on employment services are common. Though it varies from firm to firm, approximately 10 to 15 percent of the total workforce hold managerial positions.

The quality of engineers and scientists determine much of the success of high technology firms. As high technology grows, the kinds of engineers will continue to proliferate and specialize, rendering traditional categories of electrical, mechanical, and industrial engineers inadequate to describe the scope of advanced technological engineering. Already, the list of engineering job titles reflect this specialization including, to name but a few, engineers of design, microprocessing, software, microwave, product, project, process, plastics, evaluation, glass, ceramic, and tools.

Engineers who at times comprise as high as 20% of the workforce in more sophisticated firms, should have at least a Baccalaureate degree and preferably a Master's degree. Often two or more years' experience with another firm is required. Engineers in greatest demand are the so-called microprocessing, software design and hardware design engineers who usually have a strong background in computer science. About 50% more engineers will be needed each year than our colleges and universities are currently graduating.

One of the most rapidly expanding needs in high technology firms is for computer scientists, which, along with systems analysts, are regarded as very difficult to fill. Minimum requirements call for a Baccalaureate degree in Computer Science or a combination of Electronic Engineering and Computer Science. Although the current workforce of most high technology firms is comprised of about 2 or 3% computer scientists, the annual occupational demand is expected to be three times the annual increase of openings for engineers and other scientists. Computer scientists are involved in designing and regulating data systems and are expected to have increasing responsibilities in the design of software applications. Interdisciplinary degrees developed by colleges and universities can meet the demand for computer scientists, with Computer Science combined with areas such as Electrical/Electronics Engineering, Mathematics, Business Administration, Bio-Chemistry and Bio-Physics.

The urgency of demand is already accelerating efforts of some firms, such as Wang Laboratories, to establish their own degree-granting institutions of higher education.

The demand for electronic technicians, comprising, in some cases, up to 25% of the total workforce, follows closely on the heels of the demand for computer scientists. As with engineers, job titles for electronic technicians are increasing and specializing, often paralleling engineering classifications to which technicians provide supportive services.

Entry level training requirements are not especially high in terms of time involvement, often consisting of a high school diploma plus six months' training and experience in electronics. Training, according to high tech employers, should include a knowledge of general electronics, basic electronic theory, ability to use scopes, meters, and other basic equipment. Additionally, technicians should have competency and under-

standing of power circuits, diagnostic frequencies on oscilloscopes, electronic assembly system components, and the ability to construct, assemble, and explain an electronics assembly system in its most simplified form.

Levels of technicians range from entry level through senior technicians, who often are titled "Quality Control Technicians", who work closely with both engineers and computer scientists in the performance of their duties. Advanced and senior technicians are expected to be familiar with microprocessing assemblies and systems, assembly-level language, some knowledge of machine language, the ability to work in teams and the ability to help train lower level technicians.

Most high technology firms have a limited number of job openings for computer programmers, requiring their programmers to be experienced and versatile in the use of several high level languages, including Fortran, Pascal, Basic 2, Basic 4, and Cobol. At the present time, the proportion of computer programmers in the workforce ranges from one to six percent and toward the end of the decade, up to 10 percent of the high technology workforce may be engaged in programming. It is anticipated that a leveling off will occur at that time as software application packages become increasingly used.

Persons interested in computer programming will find the best chances for entry-level employment in other than high technology firms and should acquire at least an Associates degree or its equivalent.

Electronic drafters/designers are in critical short supply in high technology industries. High technology employers express frequent frustration when vocational-technical schools continue to train architectural drafters, whom they do not need. Greater degrees of recruitment success are attained in working with community colleges and electronics trade schools.

High technology employers report an increased need for technical writers within the next several years. Many of those now employed in administrative and technical services have been used in technical writing, but with less than satisfactory results.

"User documentation" explains the fundamental objective of technical writing in the high technology industry. Qualifications of technical writers include a thorough hands-on knowledge of the equipment, hardware, system assemblies, and software programs. Without these, the most capable journalist or writer will fail to deliver. The hiring tendency is to search out engineers and technicians who have a flair for writing rather than writers who have an interest in electronics. College students interested in technical writing careers are advised to take a diversified multidisciplinary program including courses in computer science, electronic theory, digital and analytic applications, business communications, liberal arts, social science, natural science, education and technical writing.

The high technology employers interviewed attach considerable importance to a segment of the workforce classified as "administrative and secretarial personnel". A number of employers regarded positions for a "qualified secretary" as among the most difficult to fill. The secretary in a high-technology firm is usually much more than a clerk-typist. Often the principal contact person for the firm, the secretary, has responsibilities in communications, coordination, and administration in helping to carry out the orders and coordinate the activities of managerial, professional, paraprofessional, and technical personnel of the firm. More and more, high technology firms are looking for persons with special communications, leadership, writing, and problem-solving skills rather than the simplified requirements of being able to type and file reports.

Liberal arts graduates and business graduates from community/junior colleges who are equipped with at least mediocre skills with a willingness to upgrade those skills are prime recruits for administrative and secretarial personnel. The so-called office of the future mandates skill upgrading and opens constant advancement possibilities for this category of workers.

Finally, a major need of most high technology firms is for assemblers and other general production workers which may comprise from 20% to 70% of the total workforce, depending upon the level of sophistication of the firm. Many start-up operations in new plant extensions focus on assembly activities. Most high tech firms are willing to train their own assembly workers. Through the use of color coding, new assemblers can learn their job within several days of on-the-job training. Advancement to technician positions is likely for those willing to undergo additional training. Although special advance training is not usually needed for assemblers, the supply of available workers can be increased by promoting electronic course offerings in the voke-tech high school or the industrial arts programs of comprehensive high schools.

Energy Technology

The Greater Fall River area may become a labor market for an advance in energy technology with the proposed establishment of a coal gasification facility currently undergoing feasibility studies by E.G. & G. Employment projections are made on a graduated basis depending on plant output which is scheduled to start-up at 10K/ton/day, gradually increasing to 20K/ton/day when approximate employment levels would be around 1,000.

The largest cluster of employees, nearly 57% of the total workforce, will consist of plant operating personnel. Eighty percent of these workers will require vocational-technical training for positions including pipefitters, welders, and laborers.

Supervisory personnel will be comprised primarily of chemical, struc-

tural, and electrical engineers. A small number will call for MBA degrees.

Laboratory employees will be comprised of both secondary and post-secondary graduates. Lab assistants will be drawn from technical school programs geared to analytical work in the field of chemistry. Laboratory specialists will be made up of chemists with a minimum of a Bachelor of Science degree. Some engineering components will be helpful since the in-plant career tract will promote laboratory chemists to managerial positions which require engineering backgrounds.

Other job demands include public safety personnel, secretarial and clerical employees, and technical advisors in welding, machine shop, and boilermaking.

Health Care

The ten health care institutions interviewed in the study included hospitals, nursing homes, health planning agencies, and health care service agencies. Urgent occupational needs for growth and replacement are evident. Additionally, new positions are constantly being created with the advent of new technologies.

Registered nurses are in short supply, especially in the evening and early morning shifts. Compounding this shortage, new technologies place increased pressure for more college education for nurses, which is already at a required four-year level in some states. Especially in the Fall River area, nurses and other health care professionals and paraprofessionals are faced with the increasing need for training emphasis in the area of germotology. Employers reiterated that the aging characteristics of the population level them underprepared to meet the needs of patients. This trend will continue, compounding the need for increased germotological components in all areas of health care.

Other traditional health care job categories continue to be in demand: LPN's, Health Aides, Technicians, Therapists, Dietary Workers, and Health Administrators.

Significant impact will be felt by the health care industry as Health Maintenance Organizations (HMO's) gain a stronger foothold in the health services of the future. Interrelated with the development of HMO's, if not a key factor contributing to their development, is the need to regain control over the financing of health care. An HMO is basically a prepaid health insurance plan where the organization and participating physicians accept contractural responsibility for the delivery of a stated range of health services. Unlike the fee-for-service sector, the HMO and its physicians have incentives to contain costs. Further, there is little doubt that HMO's are here to stay. Enrollment increase during an 18-month period (1978-1980) raised the total number of enrollees to 7 million people nationwide.

The direct effect on the labor market is the increased need for technicians because of an increased use of medical-technological devices that require special training not usually associated with a physician's training. There will be a steady increase in mid-level professional health care specialists and RN nurses. Personnel with skills appropriate to fill these occupations will be in great demand over the next decade and beyond, moving health care to neighborhood health producing centers and transforming hospitals to long-term, critical care facilities with advanced technology particularly in radiologic and nuclear medicine.

Metal Fabrication

The seven metalworking firms interviewed reported modest growth potential within existing plants, but felt little need or likelihood of expansion and/or relocation to other sites. Most employment needs are due to replacement. High demand occupations continue to be tool and die makers and machinists. While voke-tech schools can supply these workers, employers stressed the need for more apprenticeship programs. The demand most often outstrips supply. Power press operators and machine operators, positions filled by voke-tech graduates, remain in moderate demand. These traditional metal fab occupation categories are met satisfactorily, according to employers by voke-tech schools.

New but moderate demand in metalworking firms includes electronic technicians and some computer related positions. The demand for technicians will increase as automation increases; however, the nature of special orders-characteristic of metalworking firms limits wholesale automation in the foreseeable future.

Computer-related positions will include terminal operators, data entry clerks, programmers and word-processing specialists, again, related to the firm's automation needs.

Employers suggest education/training institutions emphasize machine math, blueprint reading, the "basics", and work ethic. The single most concern employers have about recent graduates is the low priority placed on work ethics and the high priority placed on "what the company can do for them" with minimal return on the part of the worker.

Summary

Studies of this nature prove to be valuable resources not only to education/training institutions and industry. They foster collaboration among all major contributions to the well-being of a local economy. Future planning is essential to future stability. We regard this as a mandate to university research centers to offer data generating services to assist the community in which it is an active, contributing corporate citizen.